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Chapter 5
Application Server Middleware

Outline

- Types of application server middleware
    - tasks
- TP monitors
- CORBA
- Server-side components and EJB
- Summary

Types of Application Server Middleware

- RPC/RMI middleware infrastructure
  - basic development and execution support
  - additional services
- TP monitor
  - transaction management, TRPC
  - process management
  - broad set of capabilities
- Object broker (e.g., CORBA)
  - distributed object computing, RMI
  - additional services
- Object transaction monitor
  - … = TP monitor + object broker
  - most often: TP monitor extended with object-oriented (object broker) interfaces
- Component Transaction Monitor
  - … = TP monitor + distributed objects + server-side component model

Middleware Tasks

- Distributed computing infrastructure (RPC, RMI)
- Transactional capabilities
  - programming abstractions (demarcation)
  - distributed transaction management
- Security services
  - authentication, authorization, secure transmission, …
- Unified access to heterogeneous information sources and application systems
- Scalable and efficient application processing
  - large number of client applications or end users
- Reliability, high availability

Programming model abstractions that allow the developer to focus on application logic (i.e., ignore infrastructure as much as possible)

Java RMI

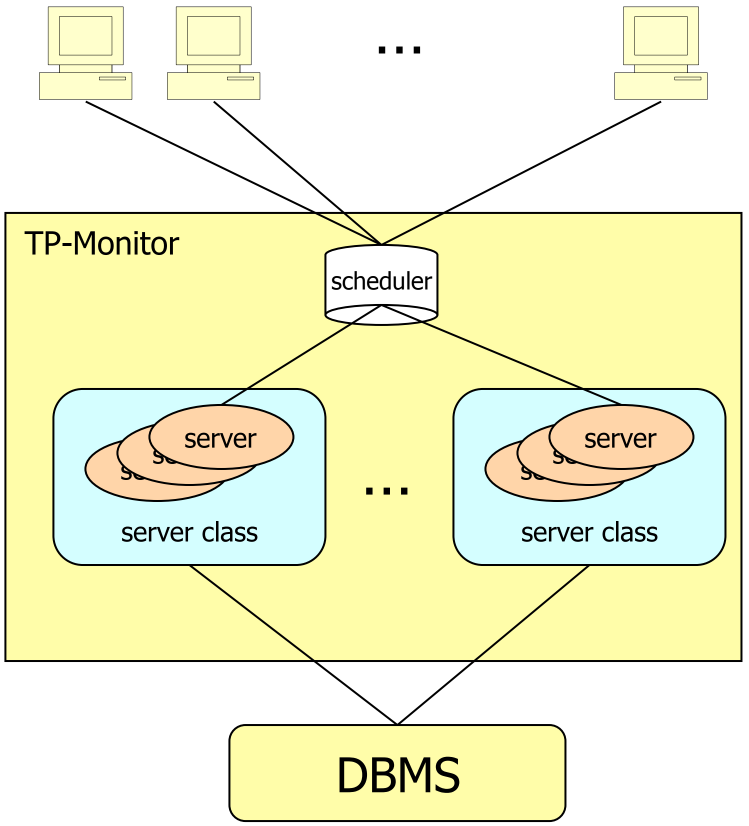
- Location-transparency
- Platform-independence
- Java only
- Additional drawbacks
  - no standardized RMI format/protocol
  - missing support for important information systems services
    - transactions, security, ...
  - no support for remaining middleware tasks

TP Monitor

- Provides functionality to develop, run, manage, and maintain transactional distributed IS
  - transaction management
  - process management
- Additional capabilities (beyond TRPC)
  - high number of connected clients/terminals (10^2 - 10^4)
  - concurrent execution of functions
  - access shared data
    - most current, consistent, secure
  - high availability
    - short response times
    - fault tolerance
  - flexible load balancing
  - administrative functions
    - installation, management, performance monitoring and tuning
- One of the oldest form of middleware
  - proven, mature technology

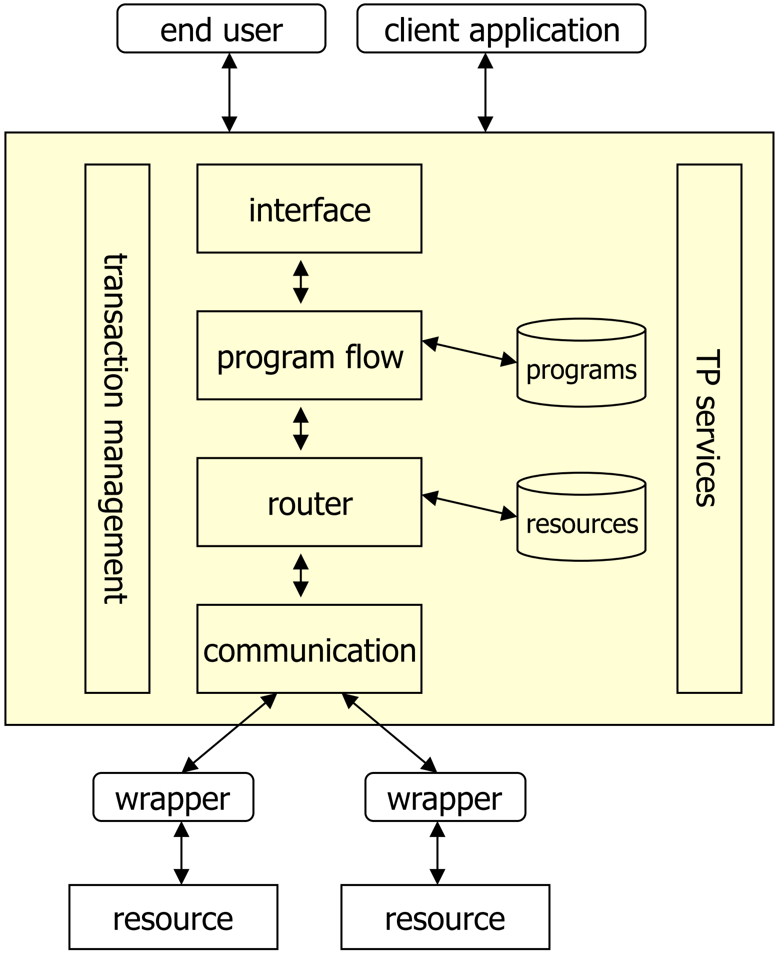
Scalable and Efficient Application Processing

- Managing large workloads
  - one process per client is not feasible
  - TP monitor manages server pools
    - groups of processes or threads, pre-started, waiting for work
  - client requests are dynamically directed to servers
  - extends to pooling of resource connections
- Load balancing
  - distribute work evenly among members of pool
  - TP monitor can dynamically extend/ shrink size of server pools based on actual workload
  - management of priorities for incoming requests



Basic Components of a TP Monitor

- Interface
  - programs and terminals
- Program flow
  - store, load, execute procedures
- Router
  - maps logical resource operations to physical resources (e.g., DBMS)
- Communication manager
  - infrastructure for communicating with resources
- Transaction manager
- Wrappers
  - hide heterogeneity of resources
- Services
  - security, performance management, high availability, robustness to failures, …



Transactional Services

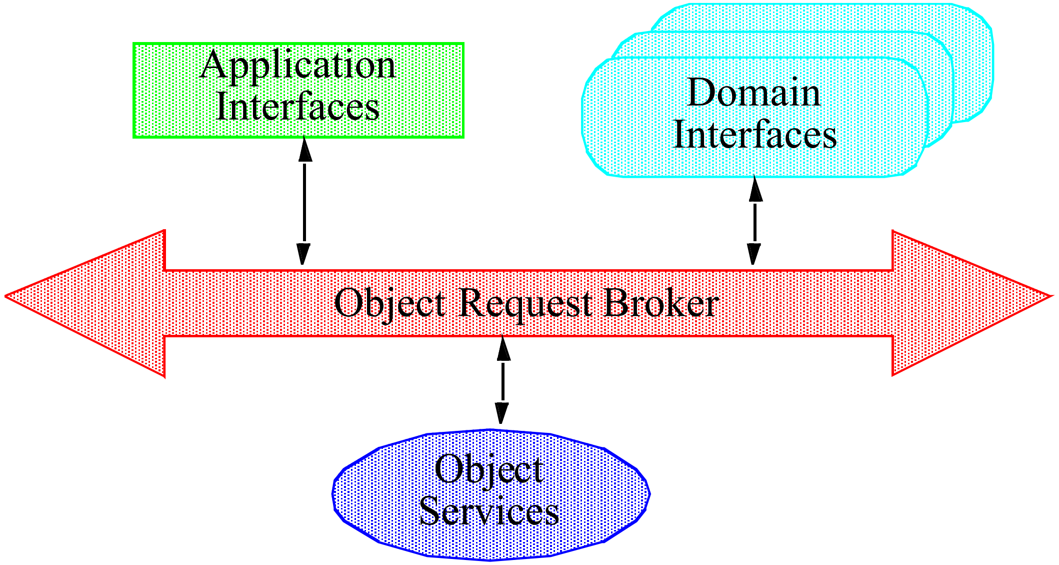
- Need to strictly distinguish TP monitor and TA manager functionality
  - many users/applications don't need a TP monitor: batch applications, ad-hoc query processing
  - special application systems (e.g., CAD) have their own (terminal) environment
  - but all need transactional support
- Separation of components for
  - transactional control (TA manager)
  - transaction-oriented scheduling and management of resources (TP monitor)

CORBA - Introduction

- CORBA: **Common Object Request Broker Architecture**
- Object-oriented, universal middleware platform
  - object bus architecture based on RMI concept
  - language-independent
  - platform-independent
- OMG
  - industry consortium (founded in 1989, 11 members)
  - today over 1000 members
  - creates specifications (no standard/reference implementations)
- First CORBA products appeared in the 90's
  - e.g., IONA's Orbix in 1993 (for C and C++)

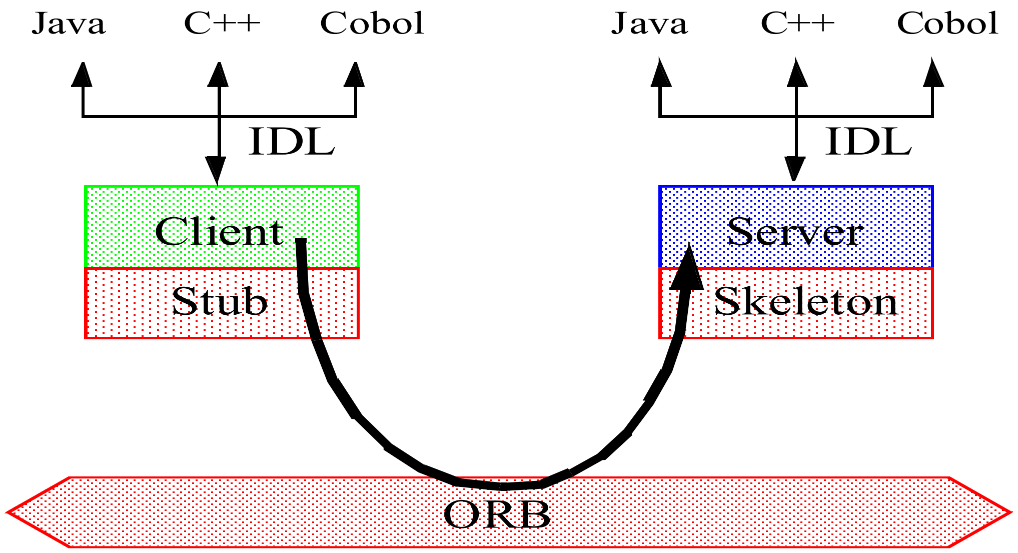
CORBA – Reference Model

- Object Management Architecture (OMA)
  - Interfaces in different categories
    - Application Interfaces
    - Object Services (horizontal)
    - Domain Interfaces (vertical)
      - Telecommunication, Finance, E-Commerce, Medicine, ...



CORBA – Interface Definition Language

- IDL defines:
  - Types
  - Constants
  - Object-Interfaces (Attributes, Methods and Exceptions)
- Independent of programming language
  - language-specific IDL bindings and compilers

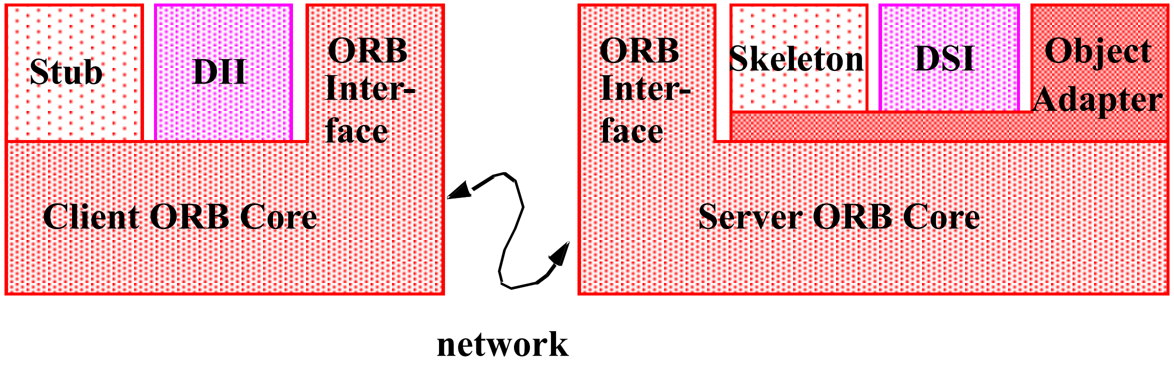


CORBA IDL - Example

```
Module PizzaService {
    interface OrderService {
          void newOrder     (in long custNo, out long orderNo);
          void addItem      (in long orderNo,
                             in long pizzaNo,
                             in long count);
                    };
    interface DeliveryService {
          long delivery(in long custNo);
                    };
          };
    interface Order {
          readonly attribute long id;  // only get-method
          attribute Date deliveryDate; // Date is an IDL interface
          void addItem(in long pizzaId, in long pizzaCount);
          };
```

CORBA – Core Components

- Object References (Interoperable Object References, IOR)
- Object Request Broker (ORB)
- Object Adapter
- Stubs and Skeletons
- Dynamic Invocation/Skeleton Interface (DII/DSI)



- Service-specific: Stub, Skeleton
- Identical for all applications: ORB Interface, DII, DSI

CORBA – ORB and Object Adapter

- ORB
  - provides network communication and connection management
  - manages stubs (client-side)
  - maps RMI to object adapter (server side)
  - provides helper functions (e.g., converting object references)
- Object adapter: Portable Object Adapter (POA)
  - generates object references
  - maps RMI to server objects
  - activates/deactivates/registers server objects
  - may perform multi-threading, …
- ORB + object adapter = request broker

CORBA – Static and Dynamic Invocation

- Static invocation
  - stub and skeleton generated by IDL compiler
  - IDL interface is mapped to specific programming language
    - static type checking (at compile time)
- Dynamic invocation
  - object interfaces (meta data) can be discovered/selected at run-time using interface repository
  - generic DII (dynamic invocation interface) operations are used to construct and perform a request
  - dynamic type checking (at run-time)
  - more flexible, but less efficient than static invocation

CORBA – “On the wire”

- Data format:
  - defines encoding of data types
  - defines responsibilities for required conversions
  - *Common Data Representation* (CDR)
- Communication protocol
  - defines client/server interactions
    - message format
    - message sequence
  - CORBA 2.0: *General Inter-ORB Protocol* (GIOP)
  - *Internet-Inter-ORB-Protocol* (IIOP)
    - maps GIOP to TCP/IP
    - internet as “Backbone-ORB”
  - optional: Environment-Specific Inter-ORB Protocols (ESIOP)
    - example: DCE Common Inter-ORB Protocol (DCE-CIOP)

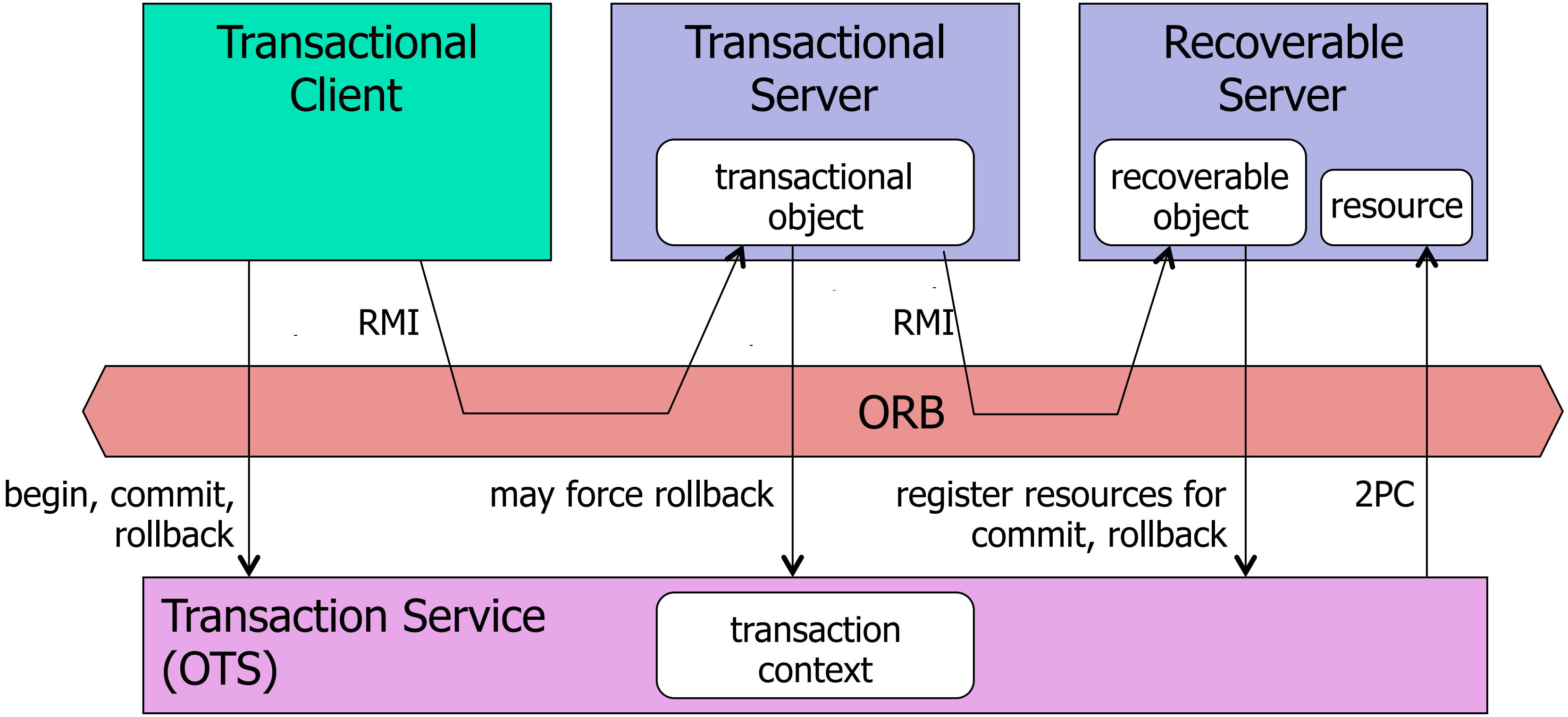
CORBA Object Services

- Goal: extend basic ORB capabilities to provide additional OTM system services
  - Naming, Life Cycle, Events, Persistence, Concurrency Control, Transaction, Relationship, Externalization, Query, Licensing, Properties, Time, Security, Trading, Collections
- Service usage
  - functionality defined using CORBA-IDL
  - CORBA object invokes method of service object
    - Example: NameService
  - CORBA object *implements* interface provided as part of a service (may not need to provide any code)
    - Example: TransactionalObject

CORBA – Object Transaction Service

- Based on X/OPEN DTP model and capabilities
  - (flat) ACID transactions
    - optional: nested transactions
  - TAs may span across ORBs
  - X/OPEN DTP
    - interoperability with "procedural" TA-Managers
- Roles and interfaces
  - transactional client
    - demarcation (begin, commit, rollback)
    - uses OTS Interface **Current**
  - transactional server
    - participates in TA, does not manage any recoverable resources
    - "implements" OTS Interface **TransactionalObject**
      - only serves as a "flag" to have the ORB propagate the transaction context
    - optionally uses OTS Interface **Current**
  - recoverable server
    - participates in TA, manages recoverable resources
    - implements OTS Interface **TransactionalObject** and **Resource**, uses **Current** and **Coordinator**
      - participates in 2PC

OTS – Elements and Interaction

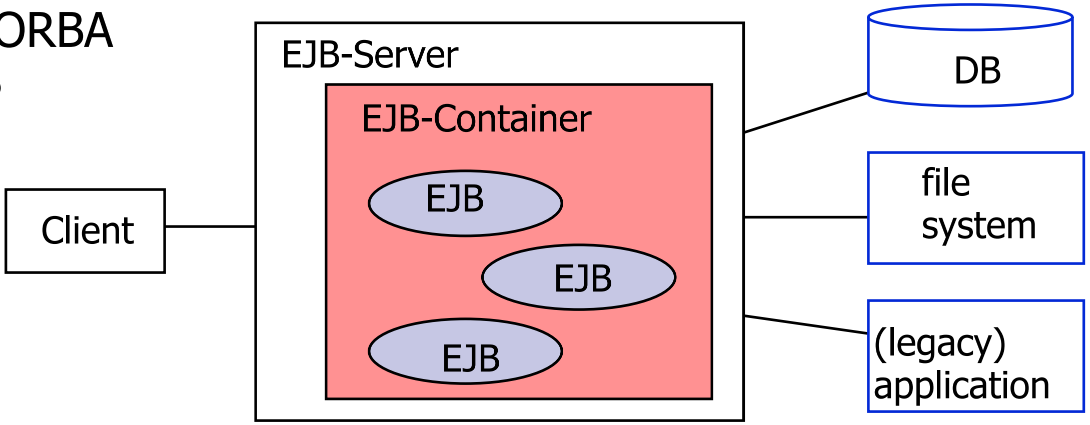


Server-side Component Models

- Problems with CORBA (up to 2.0)
  - complex, non-standard programming of server objects
    - service usage (transactions, security, ...)
      - behavior fixed at development time
    - resource management, load balancing
      - proprietary programming model and interfaces, is supported by object adapter
- Standardized Server-side component model
  - defines a set of "contracts" between component and component server for developing and packaging the component
  - developer focuses on application logic
    - service use can be defined at deployment time by configuring the application component
      - code generation as part of deployment step
    - resource management, load balancing realized by application server
      - component only has to fulfill certain implementation restrictions
  - server components are portable

Enterprise JavaBeans (EJBs)

- Standard server-side components in Java
  - encapsulates application logic
    - *business object components*
    - can be combined with presentation logic component models
      - servlets, JSPs
  - EJB container
    - run-time environment for EJB
      - provides services and execution context
    - *Bean-container-contract*
      - EJB implements call-back methods
- Interoperability with CORBA
  - invocation: RMI/IIOP
  - services

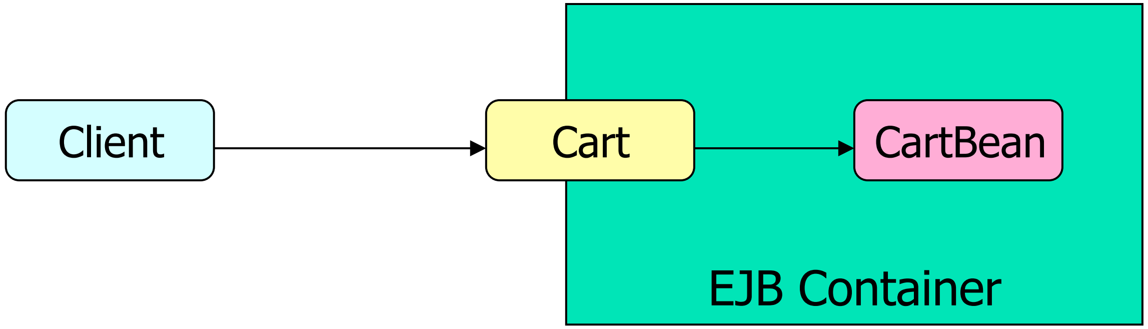


EJB – Types Of Objects

- Session Object
  - realizes business activity or process
  - often remotely accessible, “course-grained”
  - relatively short-lived (transient)
- Entity Object *(see next chapter)*
  - represent persistent, transactional business object
  - usually locally accessible, “fine-grained”
  - can be long-lived
- Message-driven Object
  - asynchronous, message-oriented invocation (see subsequent chapter)
  - facilitates integration with existing applications

EJB - Concepts

- Enterprise Bean (EB) consists of (ejb-jar file):
  - class implementing business logic (*Bean, e.g., CartBean*)
  - bean business interface, defining methods (*e.g., Cart*)
    - remote and/or local access
  - deployment descriptor/meta-data
- Client interacts with bean using *business interface object*
  - generated at deployment time
  - contains infrastructure code (transaction & security support, ...)
  - client obtains reference to interface object using JNDI (or dependency injection)



Session Beans

- Realization of session-oriented activities and processes
  - isolates client from entity details
  - reduces communication between client and server components
- Session beans are transient
  - bean instance exists (logically) only for duration of a "session”
- *stateless* session bean
  - state available only for single method invocation
- *stateful* session bean
  - state is preserved across method invocation
    - session context
  - association of bean instance with client necessary
- *singleton* session bean
  - a single bean instance is shared across applications with concurrent access support
- not persistent, but can manipulate persistent data
  - example: use JDBC, SQLJ to access RDBMS

Example

- look up Cart interface

  ```
  @Resource SessionContext ctx;      //use dependency injection to obtain JNDI context
  Cart cart = (Cart) ctx.lookup(“cart”); //perform lookup, autom. creates EB object
  ```

- call method to initialize bean

  ```
  cart.startShopping(“John”, “7506”);
  ```

- invoke bean methods

  ```
  cart.addItem(66);
  cart.addItem(22);
  …
  ```

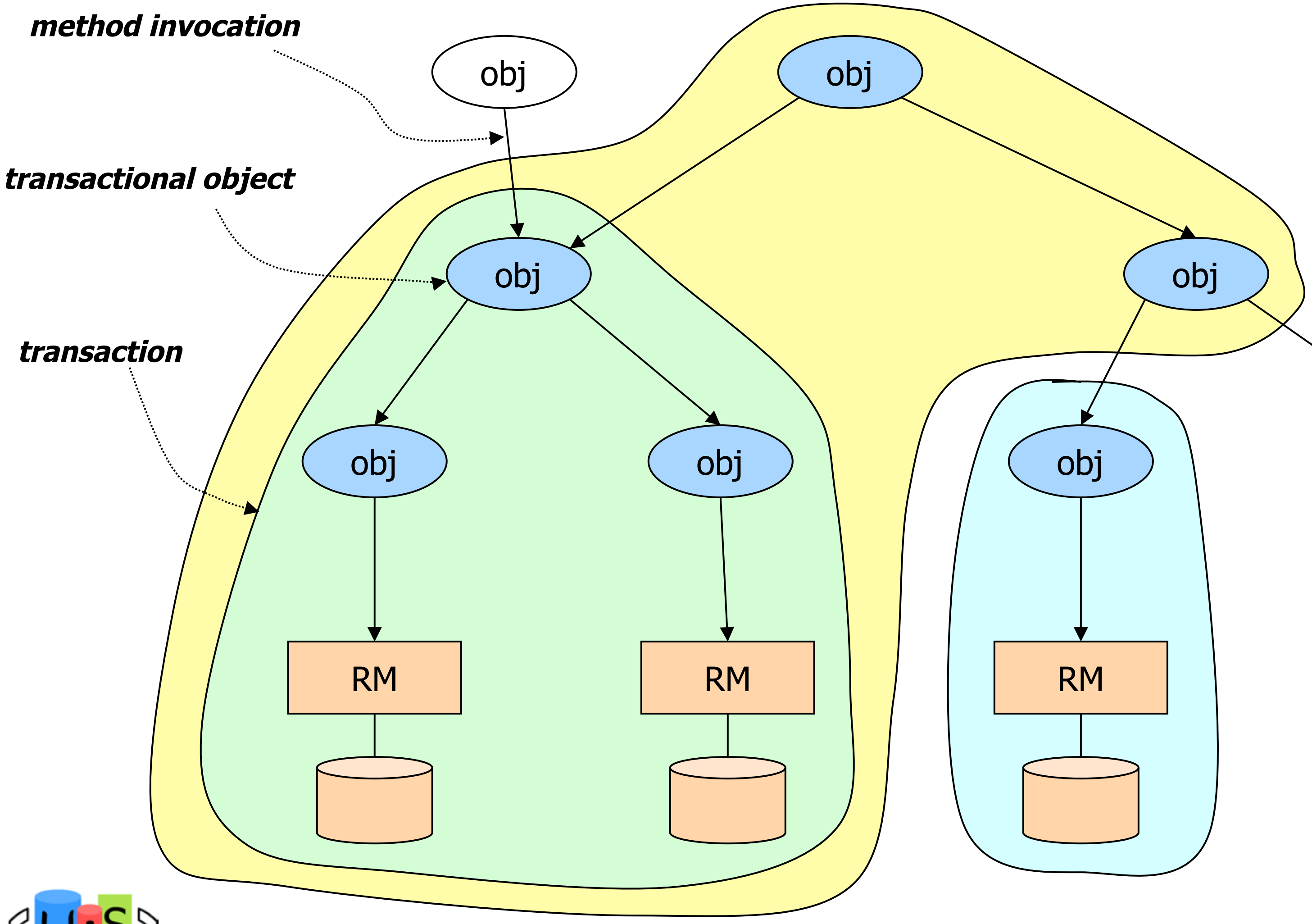
- remove session bean

  ```
  cart.close() // the “close” method was annotated/declared as a “RemoveMethod”
  ```

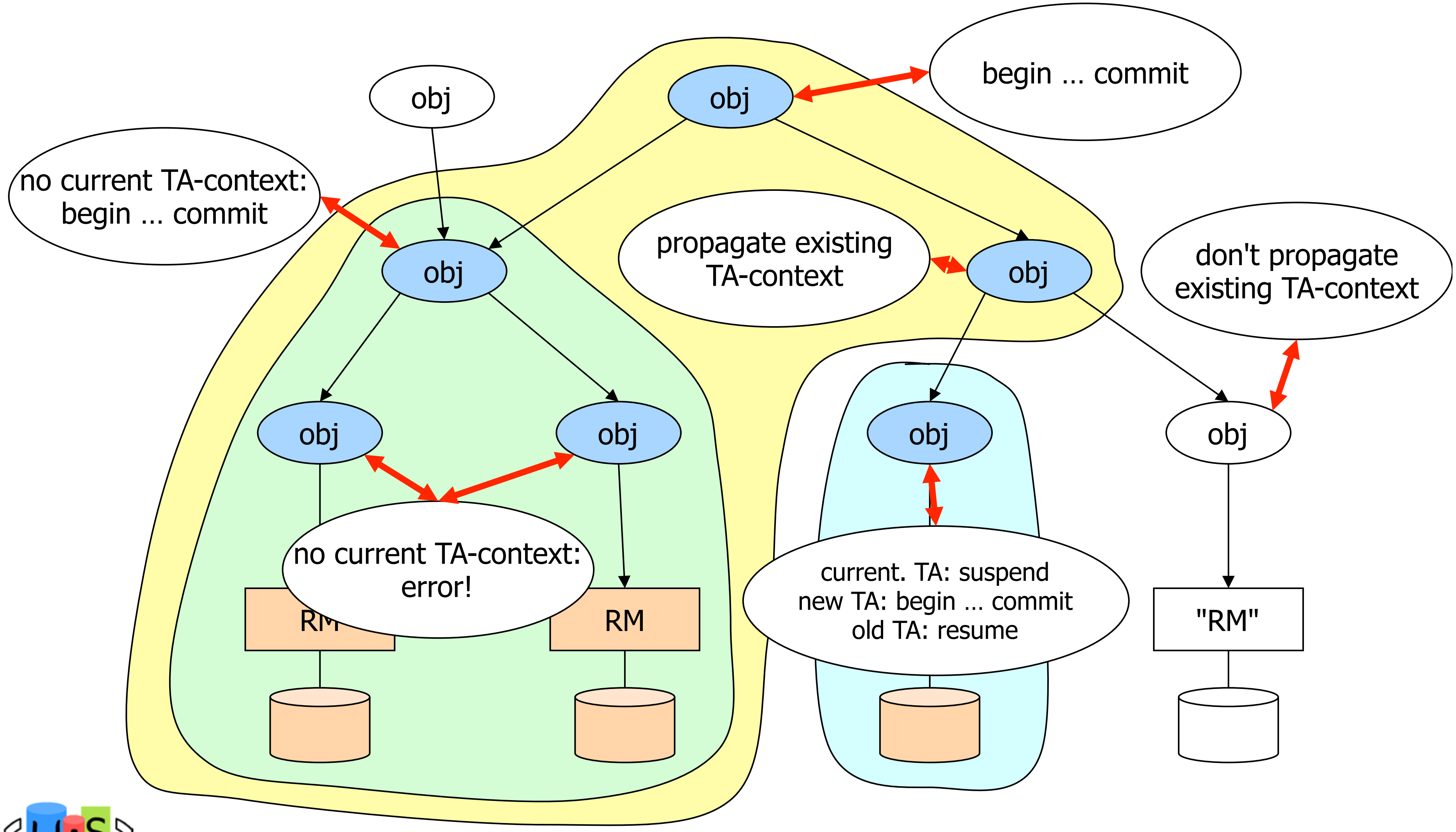
Deployment

- EB is portable, server-independent
- Component properties
  - mapping of bean attributes to DB structures
  - configuration regarding transactional behavior
  - configuration of security aspects
- Specified using
  - source code annotations (specified at development time)
  - an XML deployment descriptor (customization at deployment time)
- What happens during deployment
  - generation of glue-code based on component properties
  - make classes and interfaces known
  - setting environment/context variables

Demarcation of Transactions



Transactional Object Behavior


obj
obj
begin … commit
no current TA-context: begin … commit
obj
propagate existing TA-context
obj
don't propagate existing TA-context
obj
obj
obj
obj
no current TA-context: error!
RM
RM
current. TA: suspend
new TA: begin … commit
old TA: resume
"RM"

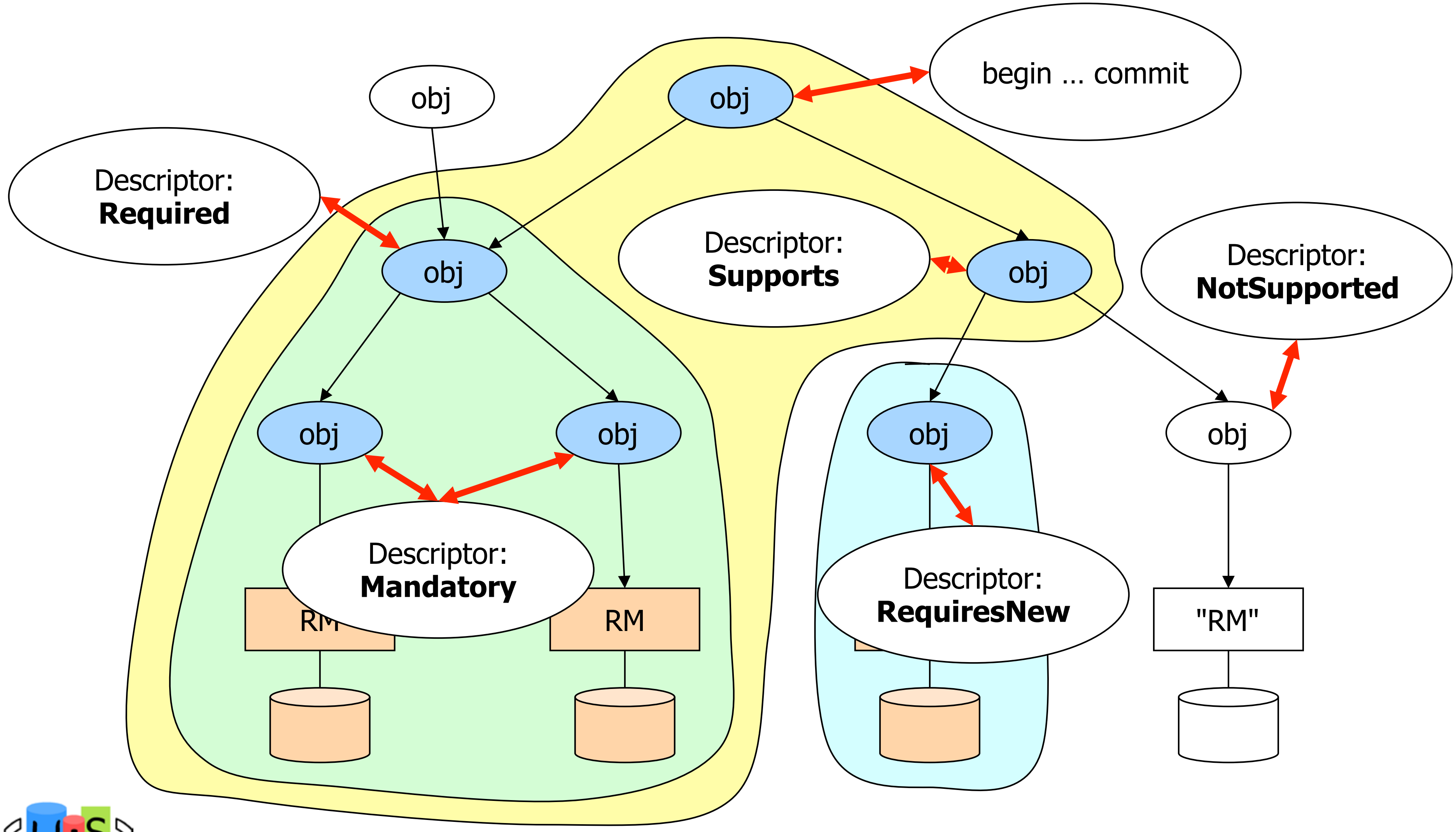
Transaction Management Approaches

- Explicit (programmatic) management
  - method interacts with TA manager using demarcation API
    - begin, commit, rollback
    - suspend, resume
  - management of transaction context
    - direct: passed along as explicit method parameter
    - indirect (preferred!): a "current" TA context is propagated automatically
- Implicit (declarative) management
  - separate specification of transactional properties
    - can be realized/modified independent of application logic
    - may be deferred to deployment phase
  - supported through container services
- Combination of both approaches in distributed IS

Explicit Demarcation with JTA

- Can be used by EJB Session Beans and EJB client, web components
  - EJB: in descriptor *transaction-type = Bean*
  - not supported for EntityBeans
- Demarcation uses JTA UserTransaction
  - *begin()* – creates new TA, associated with *current thread*
  - *commit()* – ends TA, current thread no longer associated with a TA
  - *rollback()* – aborts TA
  - *setRollbackOnly()* – marks TA for later rollback
    - beans with implict TA-mgmnt can use method on *EJBContext*
  - *setTransactionTimeout(int seconds)* – sets timeout limit for TA
  - *getStatus()* – returns TA status information
    - active, marked rollback, no transaction, ...
- Stateless SessionBeans
  - *begin()* and *commit()* have to be issued in the same method
- Stateful SessionBeans
  - *commit()* and *begin()* can be issued in different methods
  - TA can remain active across method invocations of the same bean

Implicit (Declarative) Demarcation in EJB



EJBs – Transactional Properties

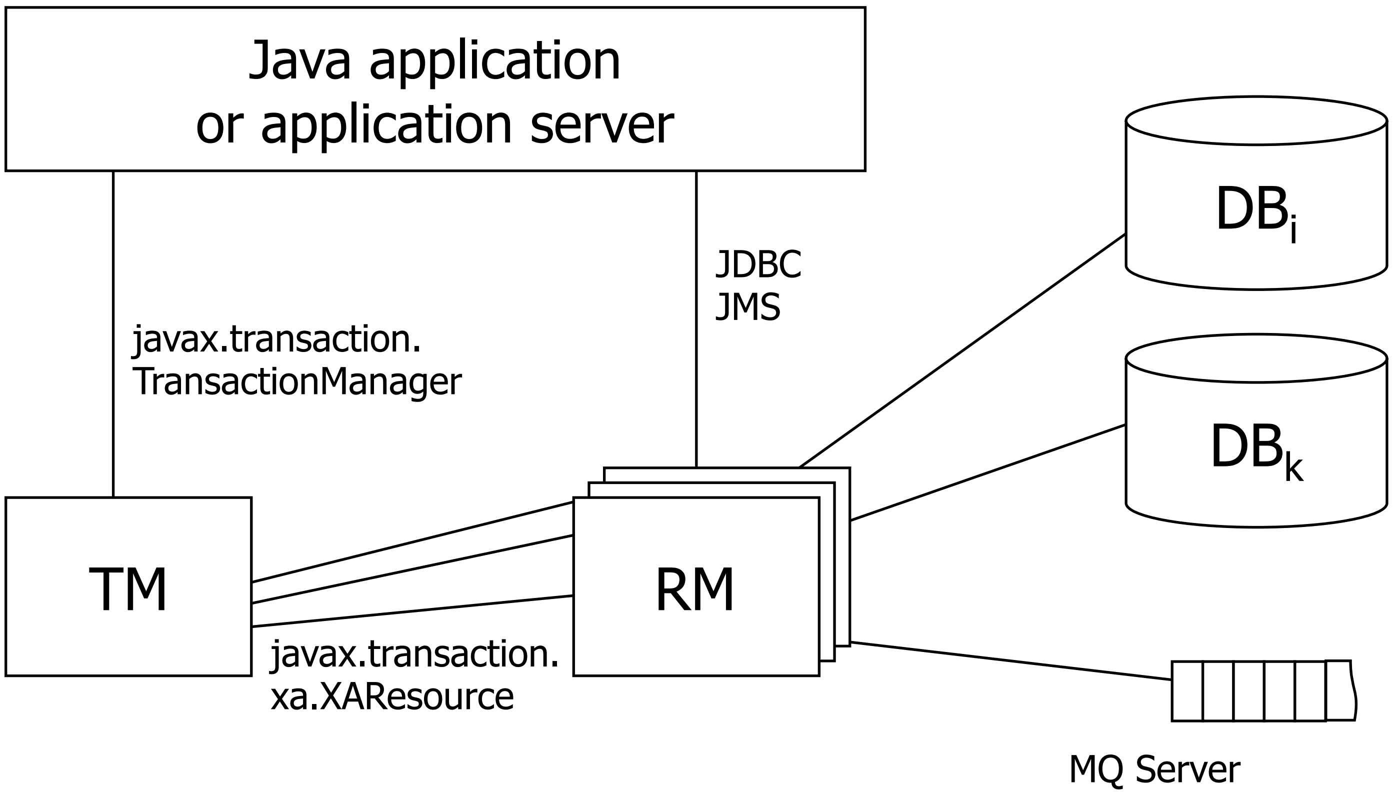
- Transaction attributes for methods specified in deployment descriptor:

TA-Attribute	Client-TA	TA in method
Not Supported	none T1	none none
Supports	none T1	none T1
Required	none T1	T2 T1
RequiresNew	none T1	T2 T2
Mandatory	none T1	error! T1
Never	none T1	none error

recommended for CMP entity beans

Transactions in Java EE

- Application component may use Java Transaction APIs (JTA)
- UserTransaction object provided via JNDI (or EJB-context)

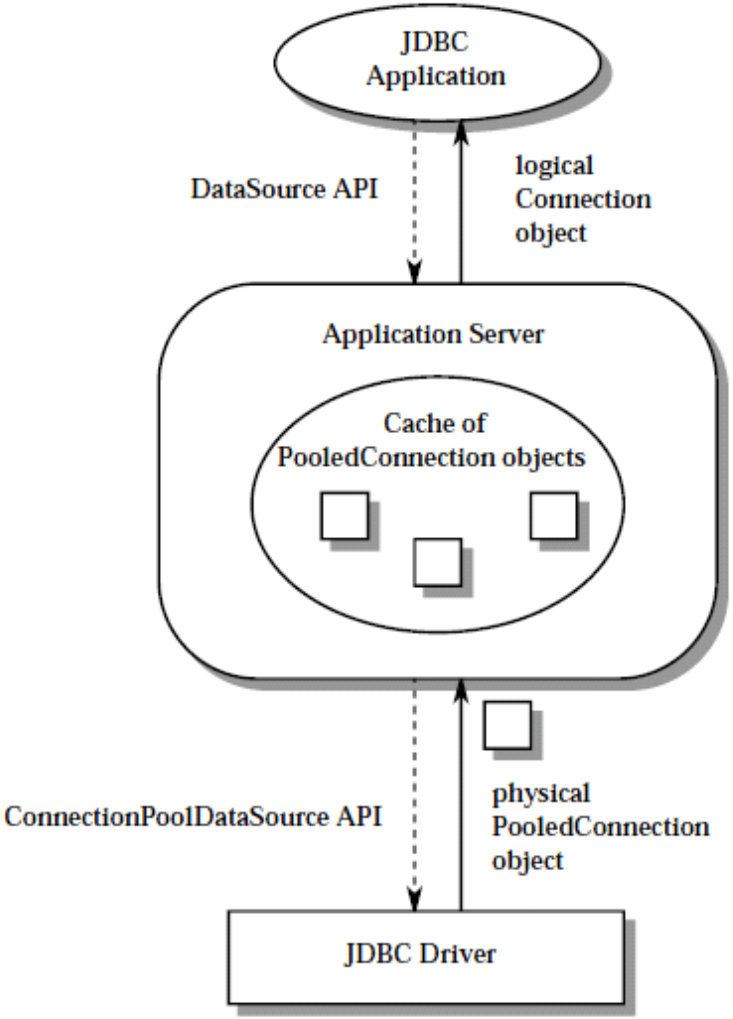


JDBC - Distributed Transaction Support

- Requires interaction with a transaction manager
  - X/Open DTP, Java Transaction Service (JTS)
- Demarcation of transaction boundaries
  - Java Transaction API (JTA)
    - UserTransaction Object
  - NOT using methods of Connection interface
- JDBC defines additional interfaces to be supported by a driver implementation to interact with transaction manager
  - XADataSource, XAConnection, ...
- DataSource interface helps to make distributed transaction processing transparent to the application

Connection Pooling

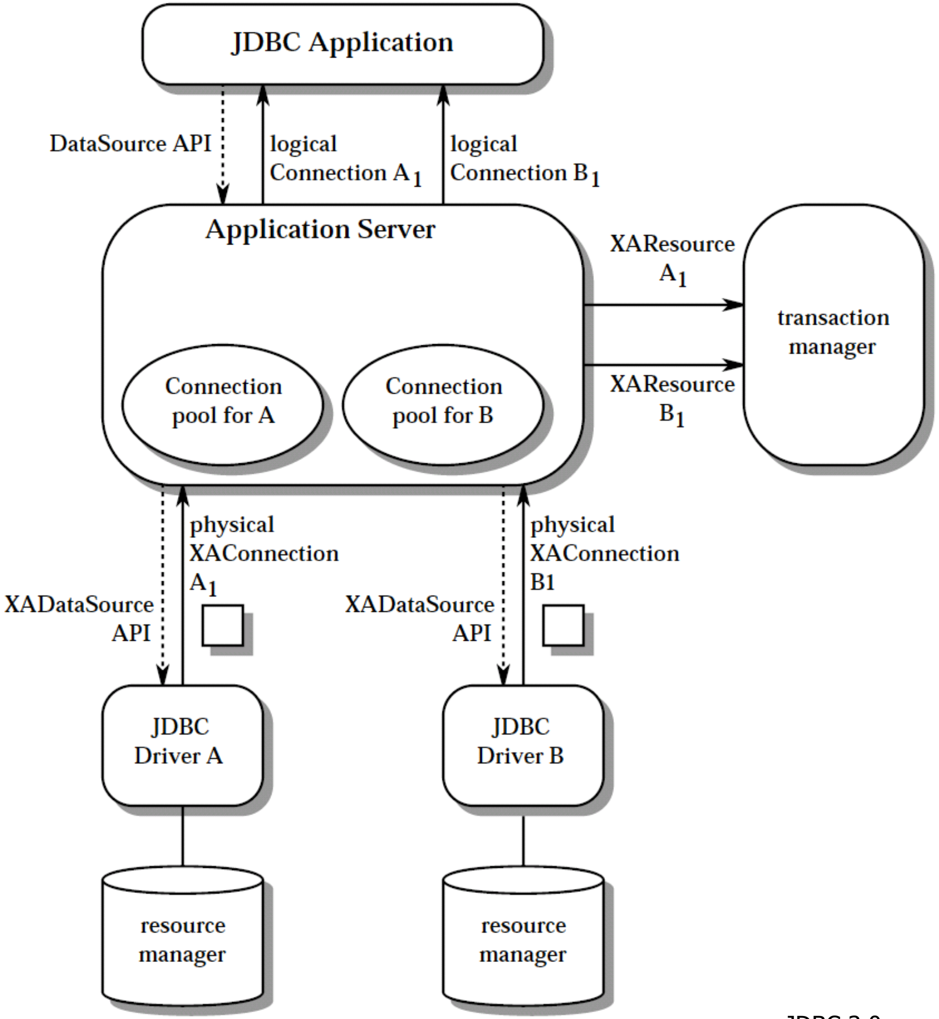
- Improves performance, scalability
  - establishing a connection is expensive
    - communication/storage resources
    - authentication, creation of security context
- Server-side application components
  - DB access often in the context of few (shared) user ids
  - connection is often held only for short duration (i.e., short processing step)
- Reuse of physical DB connection desirable
  - open -> "get connection from pool"
  - close -> "return connection to pool"
- Connection pooling can be "hidden" by DataSource, Connection interfaces
  - transparent to the application



JDBC Application
DataSource API
logical Connection object
Application Server
Cache of PooledConnection objects
ConnectionPoolDataSource API
physical PooledConnection object
JDBC Driver

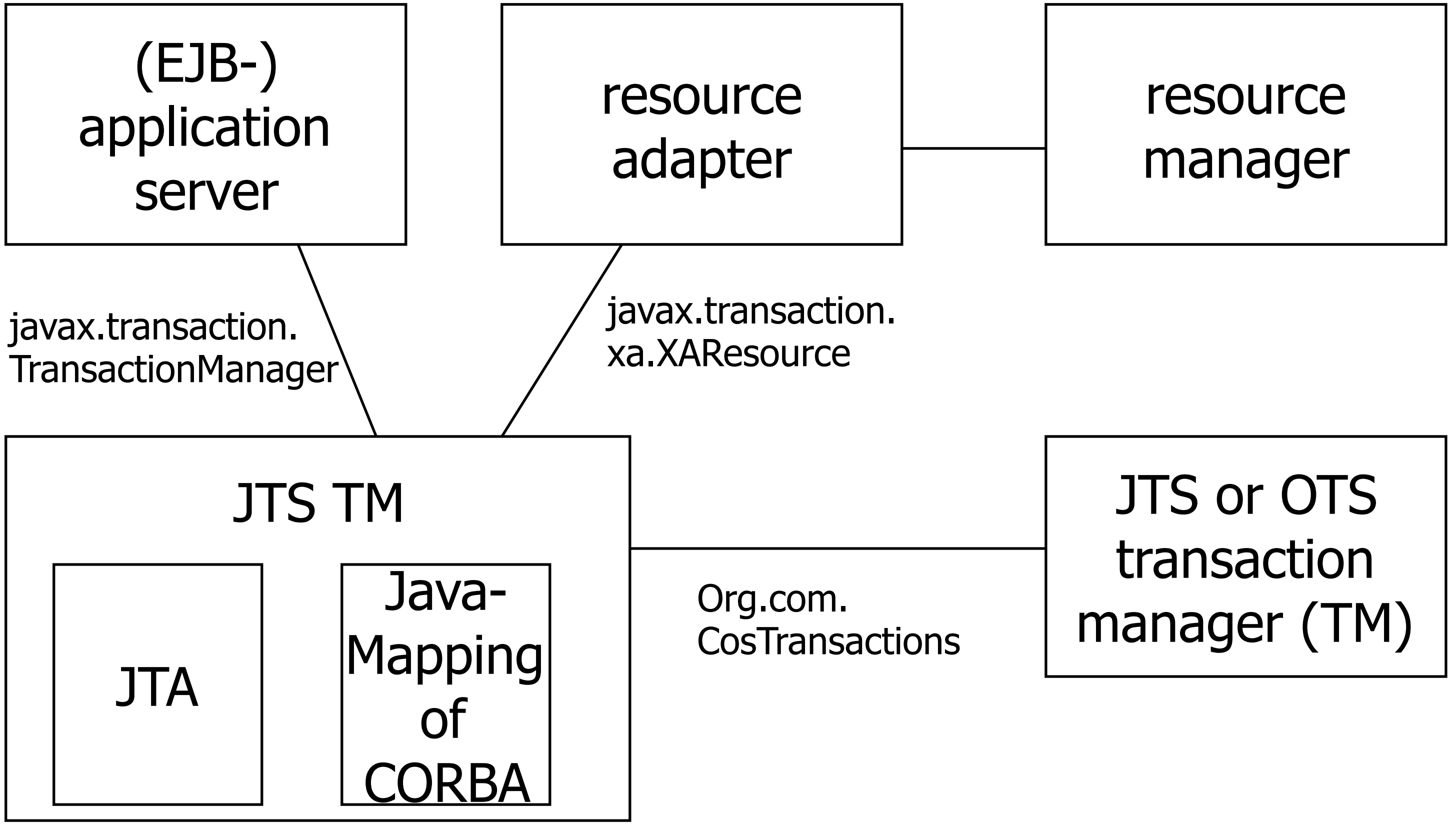
source: JDBC 3.0

Distributed Transaction Processing with JDBC



source: JDBC 3.0

JTS Architecture



(EJB-) application server

resource adapter

resource manager

javax.transaction. TransactionManager

javax.transaction. xa.XAResource

JTS TM

JTA

Java-Mapping of CORBA

Org.com. CosTransactions

JTS or OTS transaction manager (TM)

EJB Resource Management

- Traditional task of a (component) TP monitor
  - pooling of resources, load management and balancing
- EJB specification
  - *Instance Pooling* and *Instance Swapping*
    - EJB server manages (small) number of Enterprise Beans
      - reuse, dynamic selection for processing incoming requests
    - made possible by 'indirect' bean access via EJB object
    - usually only applicable for **stateless session beans** and for **entity beans**
  - *Passivation* and *Activation*
    - bean state can be stored separately from bean (*passivation*)
      - allows freeing up resources (storage), if bean is not used for a while (e.g., end user think time)
    - if needed, bean can be reactivated (*activation*)
    - uses Java Serialization
    - can also be used for **stateful session beans**
- "Disallowed" for EJB developers:
  - creating threads, using synchronization primitives
  - I/O, GUI operation
  - network communication
  - JNI

CORBA Component Model

- Motivated by success of EJB component model
- New CORBA Component Model (CCM) as middle-tier infrastructure
  - adds successful EJB concepts
  - separates implementation from deployment
  - provides container capabilities (transactions, persistence, security, events)
  - interoperability with EJBs
- Advantage: CORBA components can be implemented in various programming languages

Summary

- Distributed computing infrastructure and transactional capabilities are core application server middleware features
- Different types of application server middleware
  - TP monitors, object brokers, object transaction monitors, component transaction monitors
- Additional tasks addressed by middleware
  - security, uniform access to heterogeneous resources, scalable and efficient application processing, reliability, high availability, …
  - server-side component model
    - high-level abstractions
    - portability of server components
    - deployment phase
- Broad variance of support for these tasks
- Convergence of different types of middleware