Carnegie Mellon University
Software Engineering Institute

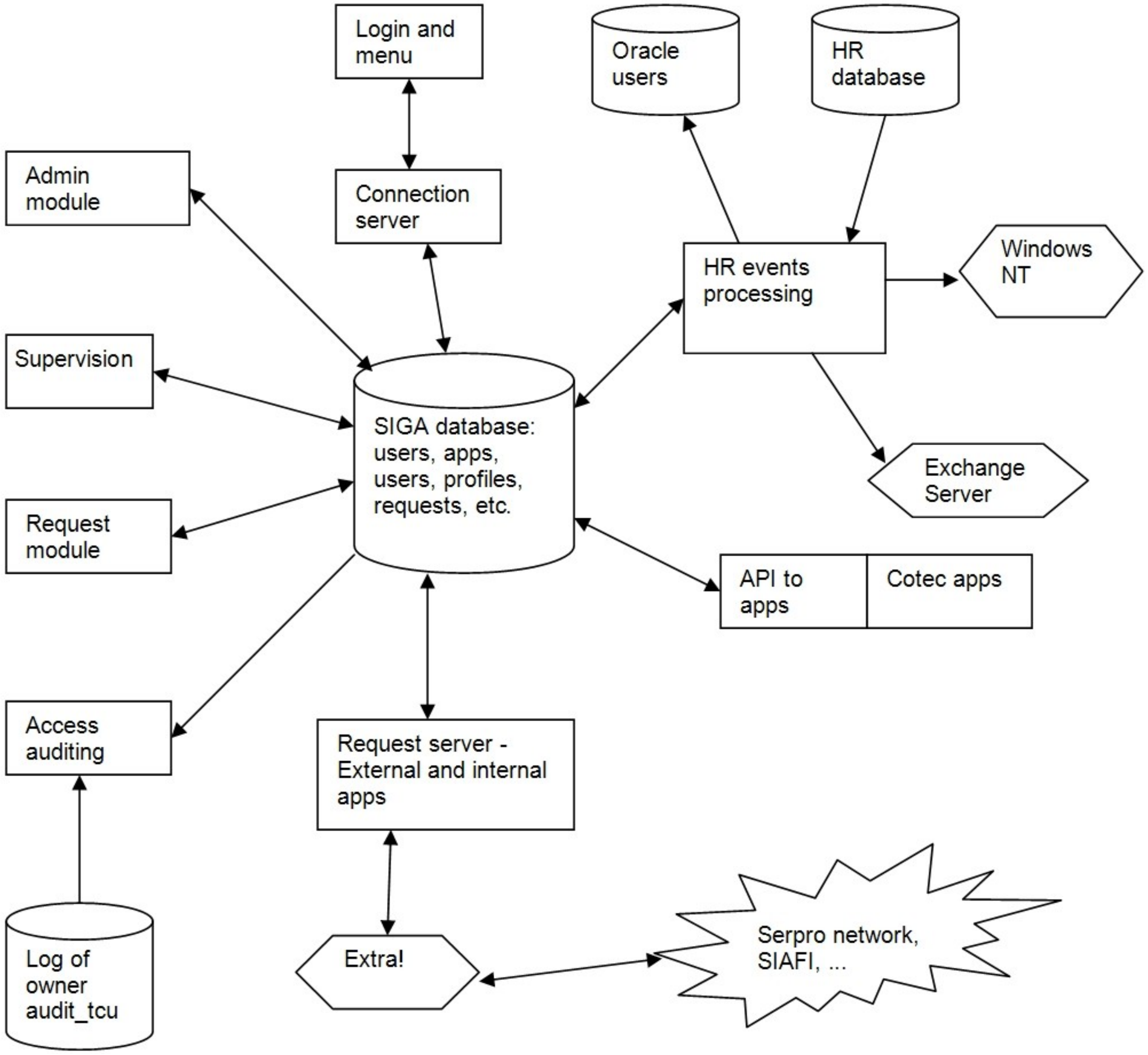
How to Represent the Architecture of Your Enterprise Application Using UML 2.0 and More

Paulo Merson

Software Engineering Institute
www.sei.cmu.edu/architecture

Session TS-4619

We Can Do Better Than This!



I created this diagram eight years ago

The design may be OK

But the design description is bad and in one hour I'll have told you why!

Goals of This Talk

- Tell you what information about an architecture should be captured
- Show you UML 2.0 and other notations and guidelines for architecture representation
- Give you a break from reading code :^)

Agenda

- Introduction
- Multi-View Architecture
  - Module Views
  - Runtime Views
  - Deployment Views
  - Data Model
- Template for an Architecture Document
- Outroduction

Agenda

Introduction

Multi-View Architecture

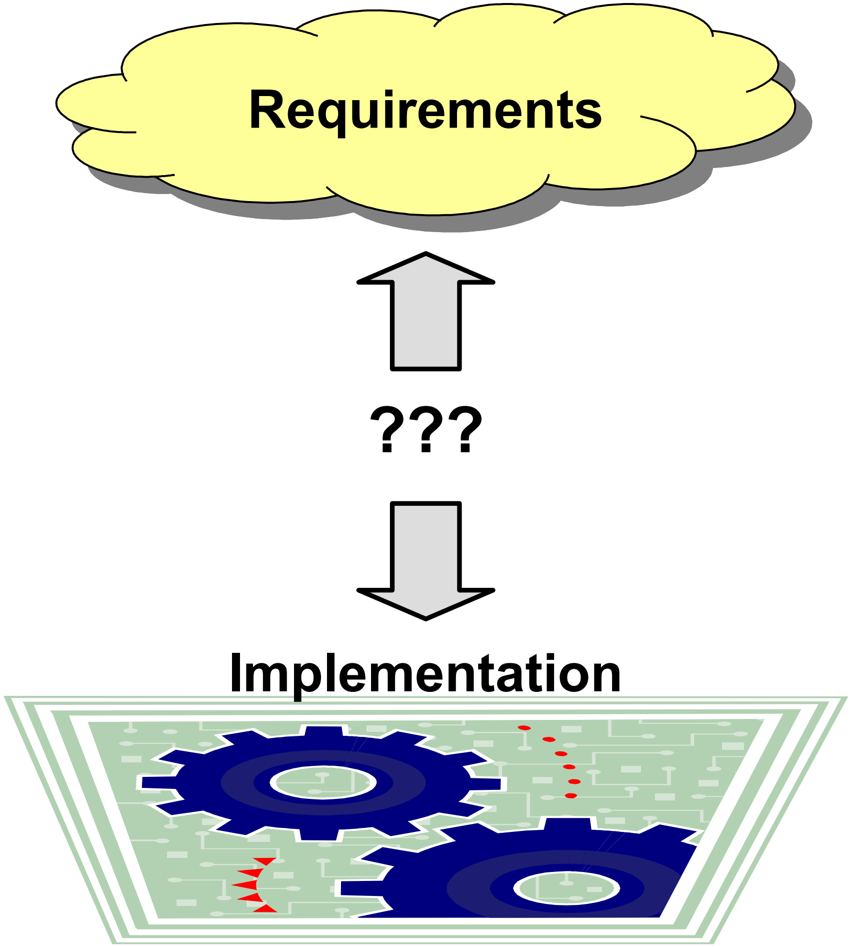
- Module Views
- Runtime Views
- Deployment Views
- Data Model

Template for an Architecture Document

Outroduction

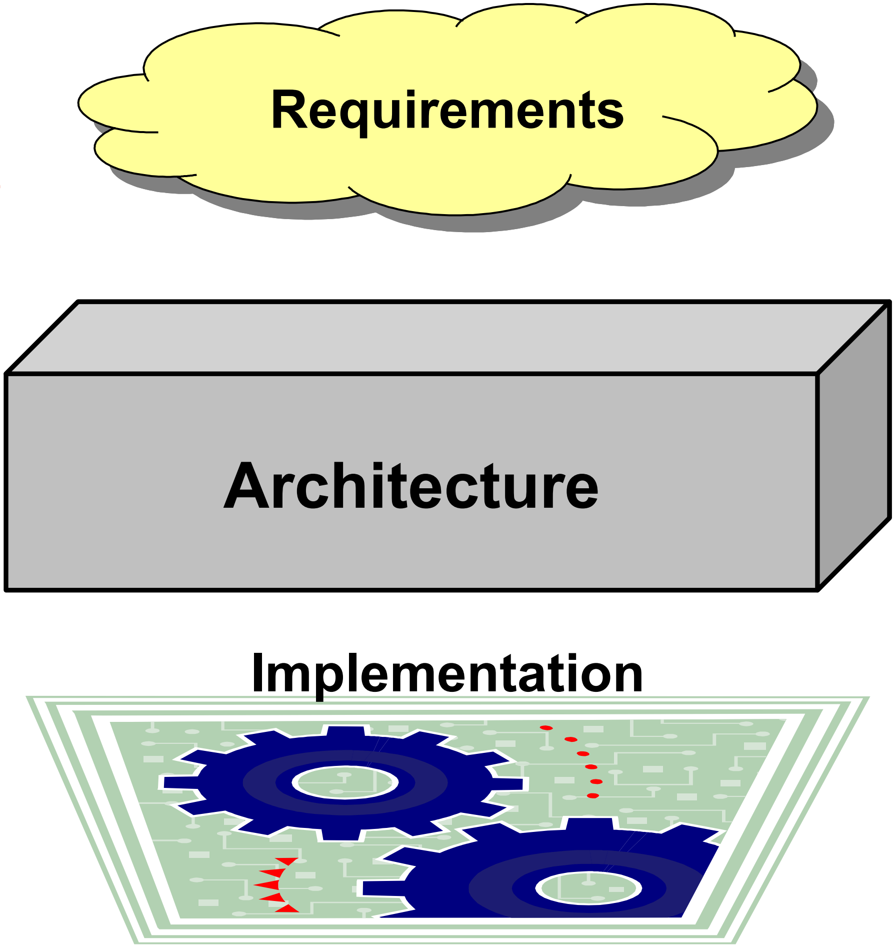
Motivation for Software Architecture(1)

The Problem



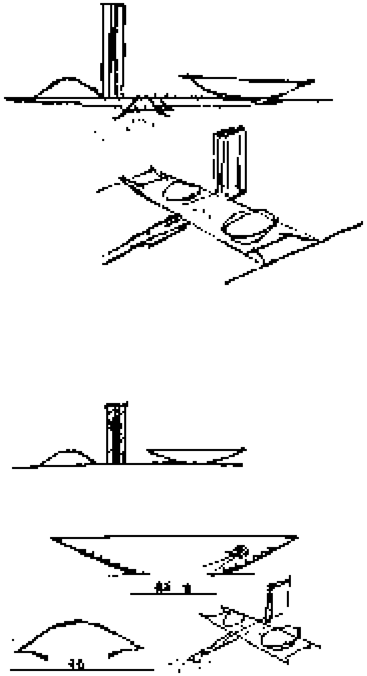
Motivation for Software Architecture[(2)]

The Role of Software Architecture



What Is Software Architecture?

A Software Architecture for a System Is the Structures of the System, Which Comprise Elements, Relations Among Them, and the Externally Visible Properties of Those Elements and Relations[1]



[1] Adapted from Bass, L.; Clements, P.; and Kazman, R. *Software Architecture in Practice, 2nd Edition*. Addison-Wesley, 2003.

Why Document the Architecture?

- In the software lifecycle we:
  - Create an architecture
    - Using architectural patterns, design patterns, experience
  - Evaluate the architecture
    - Using ATAM® for example
  - Refine, update and refactor the architecture along the way
  - Use the architecture to guide implementation
  - (Try to) enforce the architecture during implementation

Software Architecture Documentation Is the
Key Artifact in All These Activities

Agenda

Introduction

Multi-View Architecture

- Module Views
- Runtime Views
- Deployment Views
- Data Model

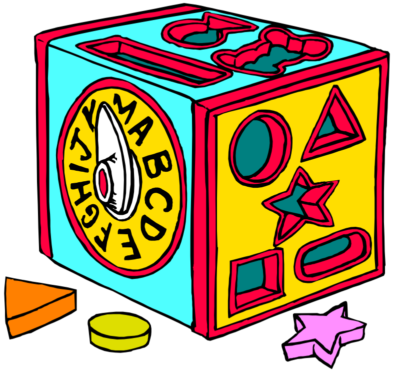
Template for an Architecture Document

Outroduction

Views(1)

- Systems are composed of many structures
  - Code units, their decomposition and dependencies
  - Processes and how they interact
  - How software is deployed on hardware
  - Many others

A View Is a Representation of a Structure, That Is, a Representation of a Set of System Elements and the Relations Associated With Them



What Views Are Available?

- An architect can consider the system in at least four ways:

  1. How is it structured as a set of code units?

     Module Views

  3. How is it structured as a set of elements that have runtime presence?

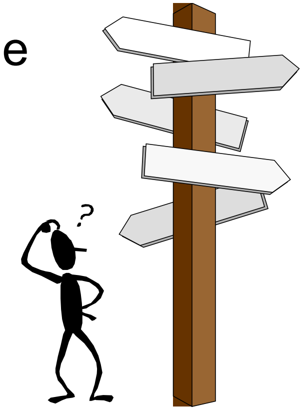
     Runtime Views

  5. How are artifacts organized in the file system and how is the system deployed to hardware?

     Deployment Views

  7. What is the structure of the data repository?

     Data Model



Agenda

Introduction

Multi-View Architecture

- **Module Views**
- Runtime Views
- Deployment Views
- Data Model

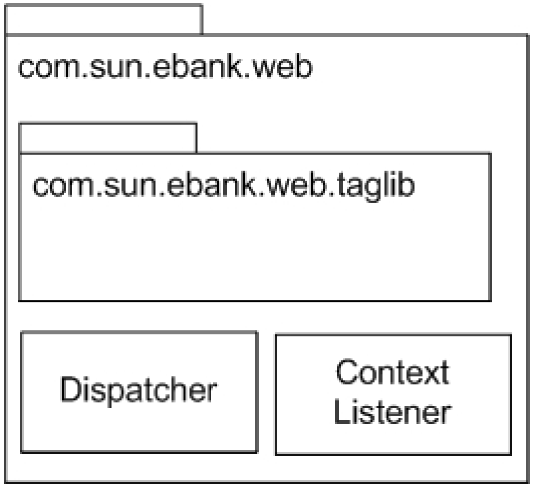
Template for an Architecture Document

Outroduction

Module Views

- Show structure of the system in terms of units of implementation
- **Elements:** modules, i.e., code units that implement some functionality
- **Relations:**
  - A is part of B: part-whole relation among modules
  - A depends on B: dependency relation among modules
  - A is a B: specialization/generalization relation among modules, or interface realization

UML Relations Between Modules


com.sun.ebank.web

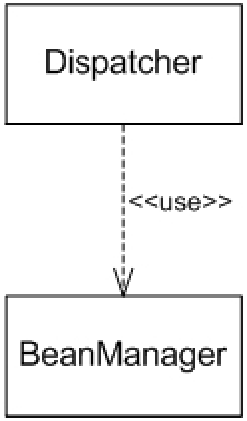
com.sun.ebank.web.taglib

Dispatcher

Context Listener

“Is part of”

Package contains subpackages or classes

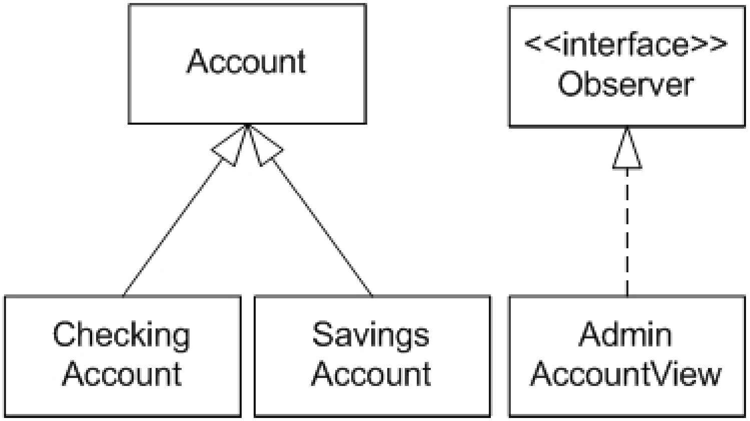

Dispatcher

<<use>>

BeanManager

“Depends on”

Dependency can be <<use>>, <<refine>>, <<instantiate>>, etc.


Account

<<interface>> Observer

Checking Account

Savings Account

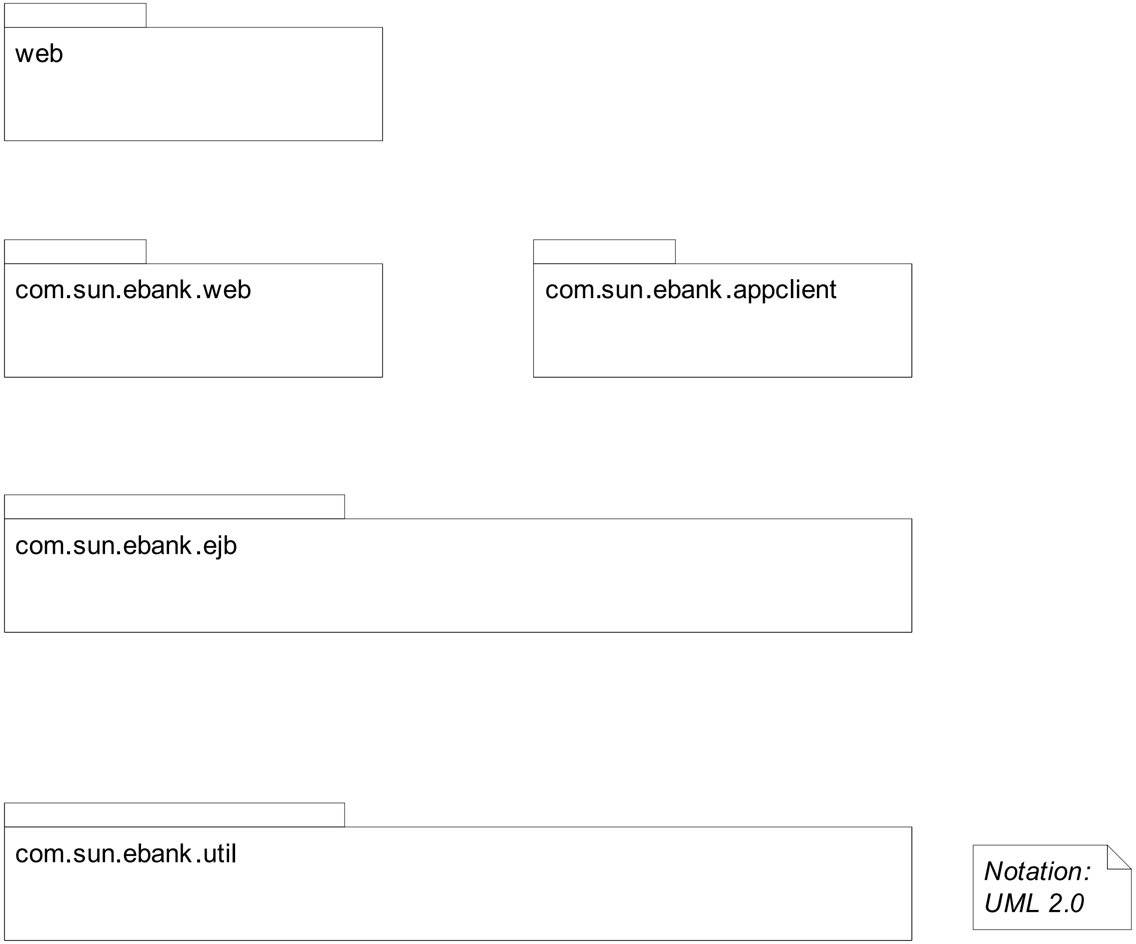
Admin AccountView

“Is a”

Generalization and interface realization

UML Has Other Standard Relations, and You Can Specialize Any of Them With Stereotypes

High-Level Module View—Duke’s Bank(1)



web

com.sun.ebank.web

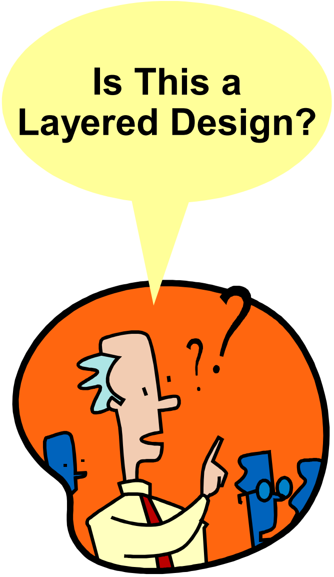
com.sun.ebank.appclient

com.sun.ebank.ejb

com.sun.ebank.util

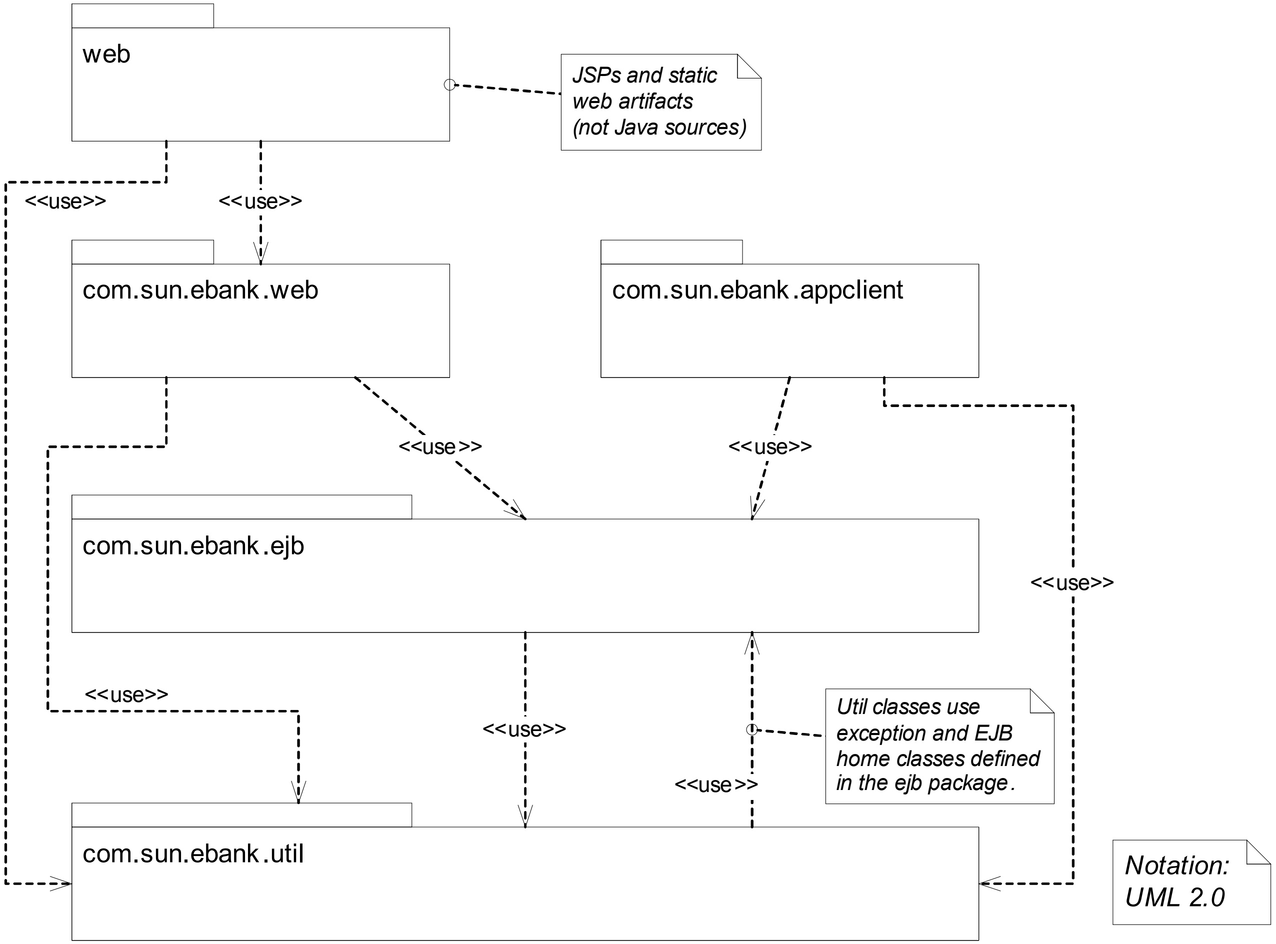
Notation: UML 2.0

Showing Only Module Decomposition



Is This a Layered Design?

High-Level Module View—Duke's Bank(2)



Showing Module Usage Decomposition

Reconstructed from Duke's Bank Application—Sun J2EE 1.3 tutorial

What Are Module Views Good For?

- Construction—they are the blueprints for the code
- Budgeting, work assignment, tracking
- Education of new developers
- Modifiability and impact analysis

Agenda

Introduction

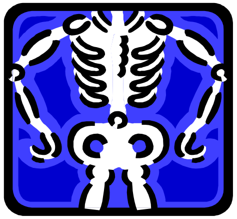
Multi-View Architecture

- Module Views
- **Runtime Views**
- Deployment Views
- Data Model

Template for an Architecture Document

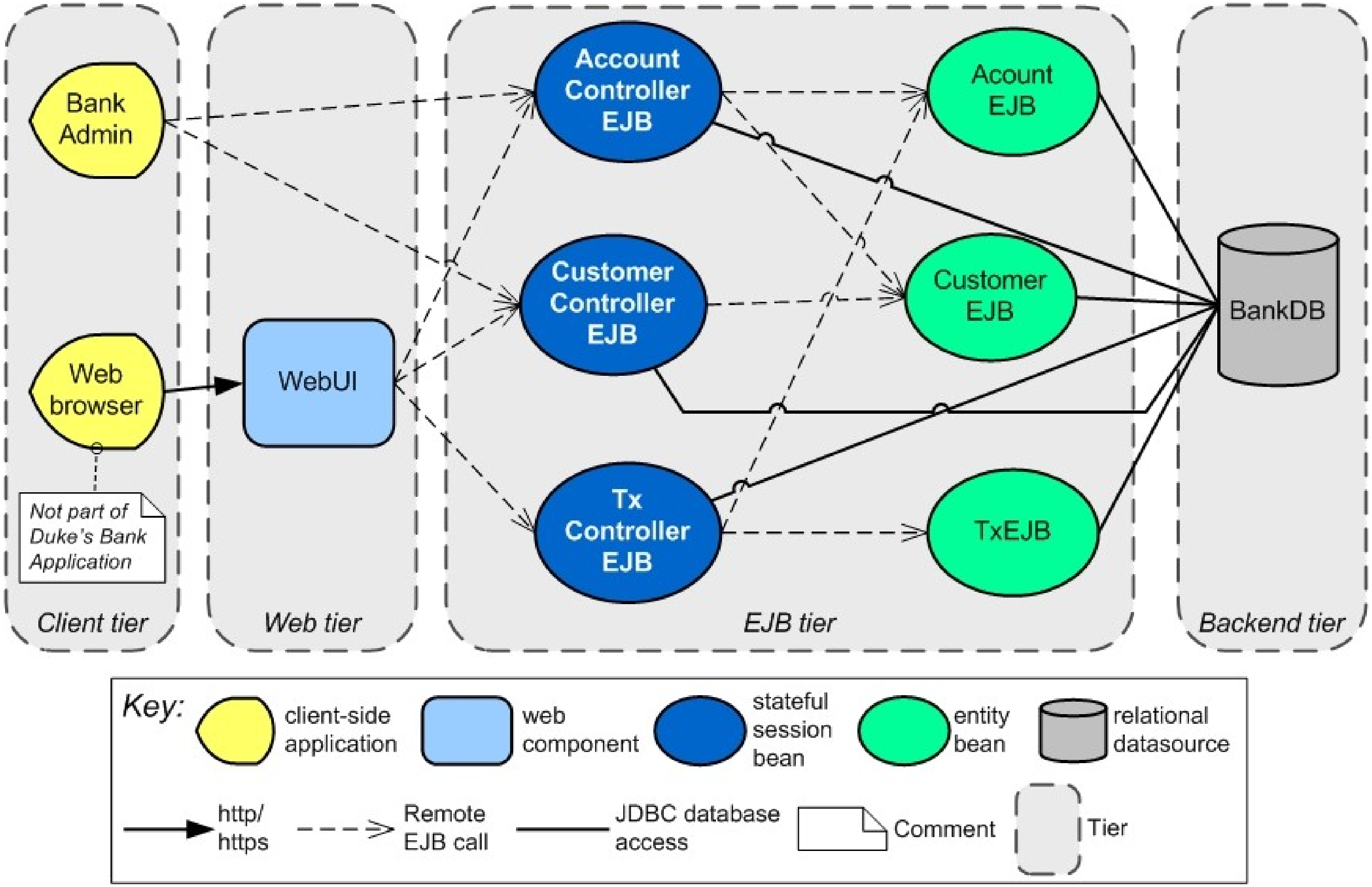
Outroduction

Runtime Views



- Show structure of the system when it’s executing
- **Elements:**
  - Components that have runtime presence (e.g., processes, threads, EJB™ components, servlets, DLLs, objects)
  - Data stores
- **Relations:**
  - Interaction mechanisms vary based on technology
  - Architect should differentiate:
    - Local from remote calls
    - Synchronous from asynchronous invocation

Runtime View—Duke's Bank

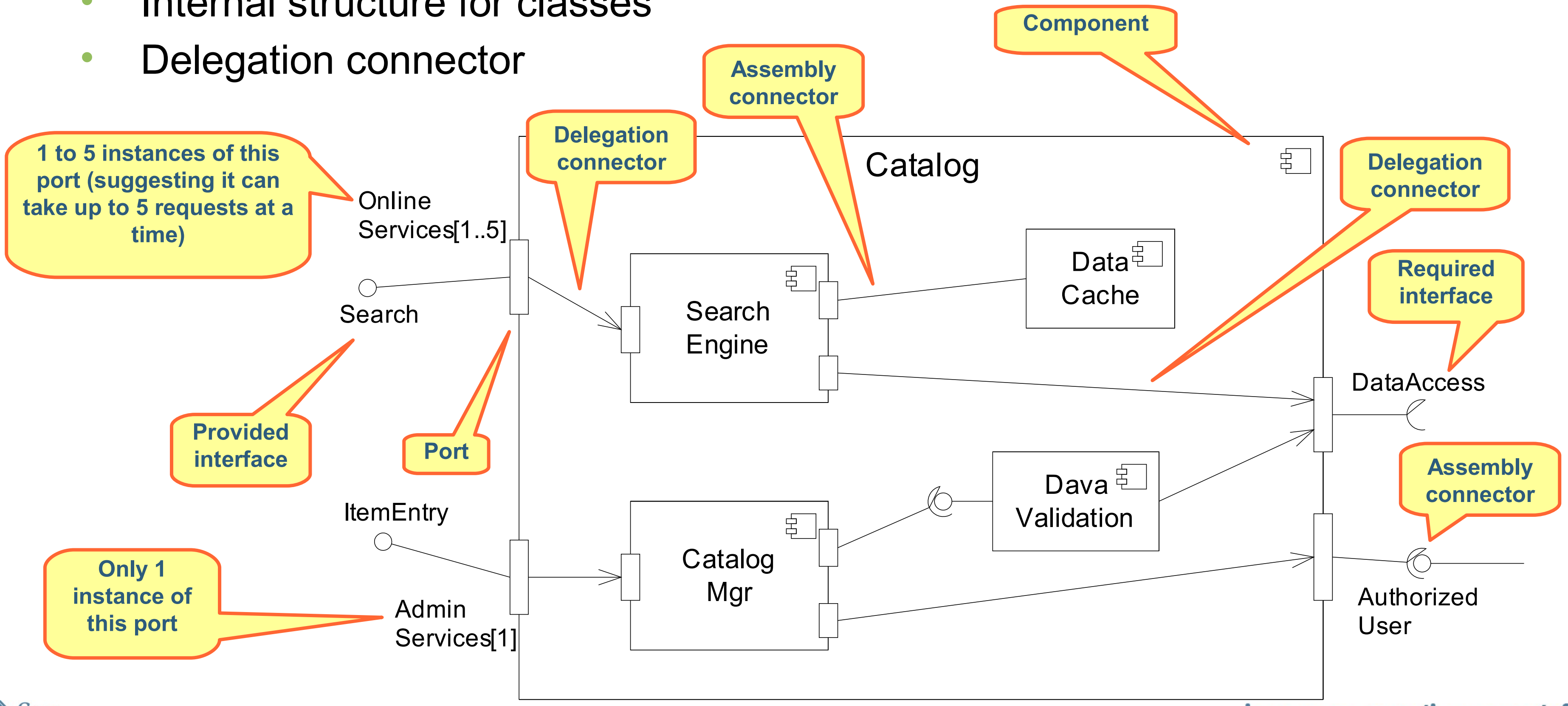


Informal Notation

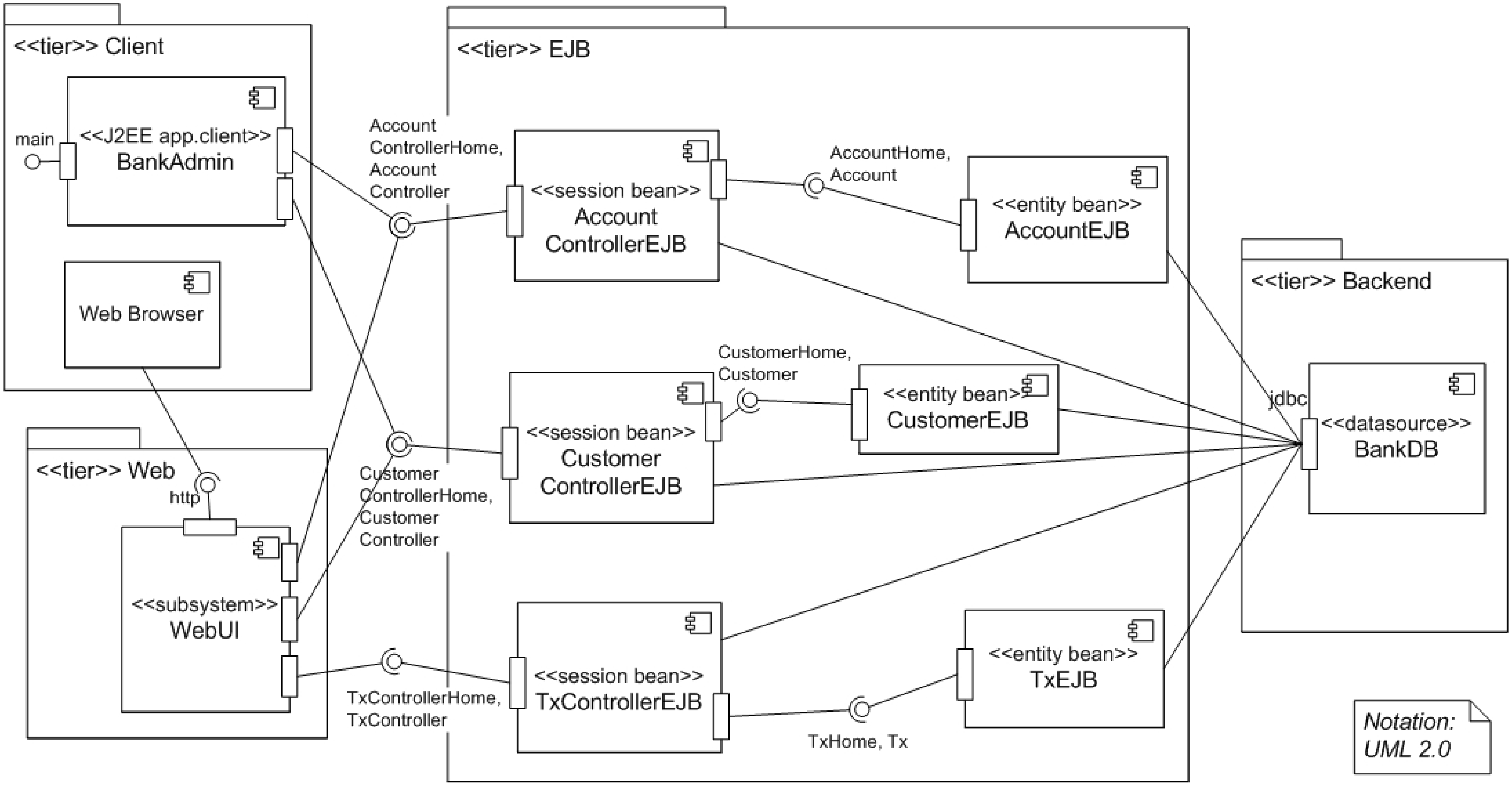
Reconstructed from Duke's Bank Application—Sun J2EE 1.3 tutorial

UML 2.0 for Runtime Views

- Component (as subtype of class)
- Port (which can have multiple instances)
- Required and provided interface (optionally connected through ports)
- Assembly connector
- Internal structure for classes
- Delegation connector

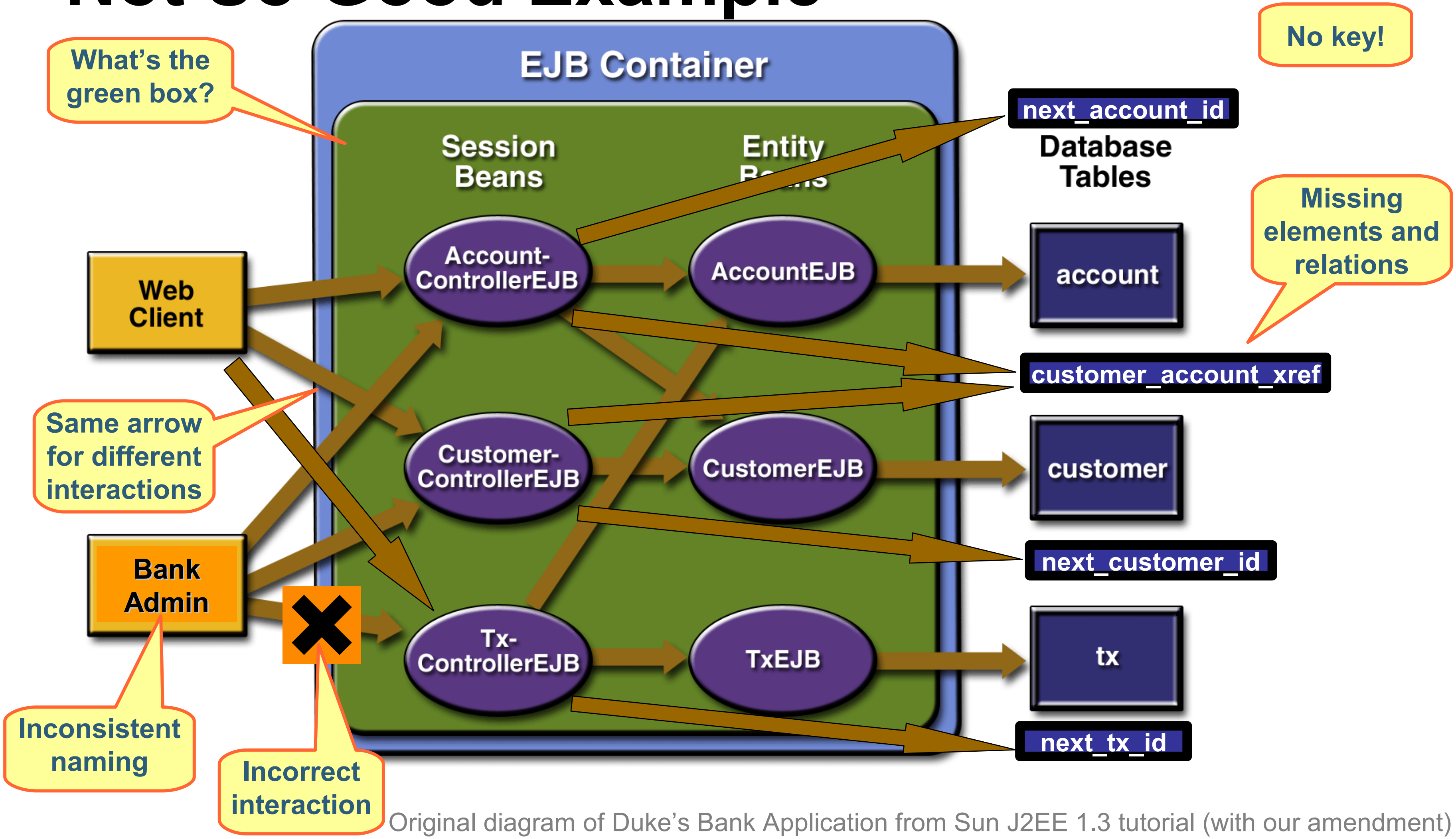


Runtime View—Duke’s Bank (UML)



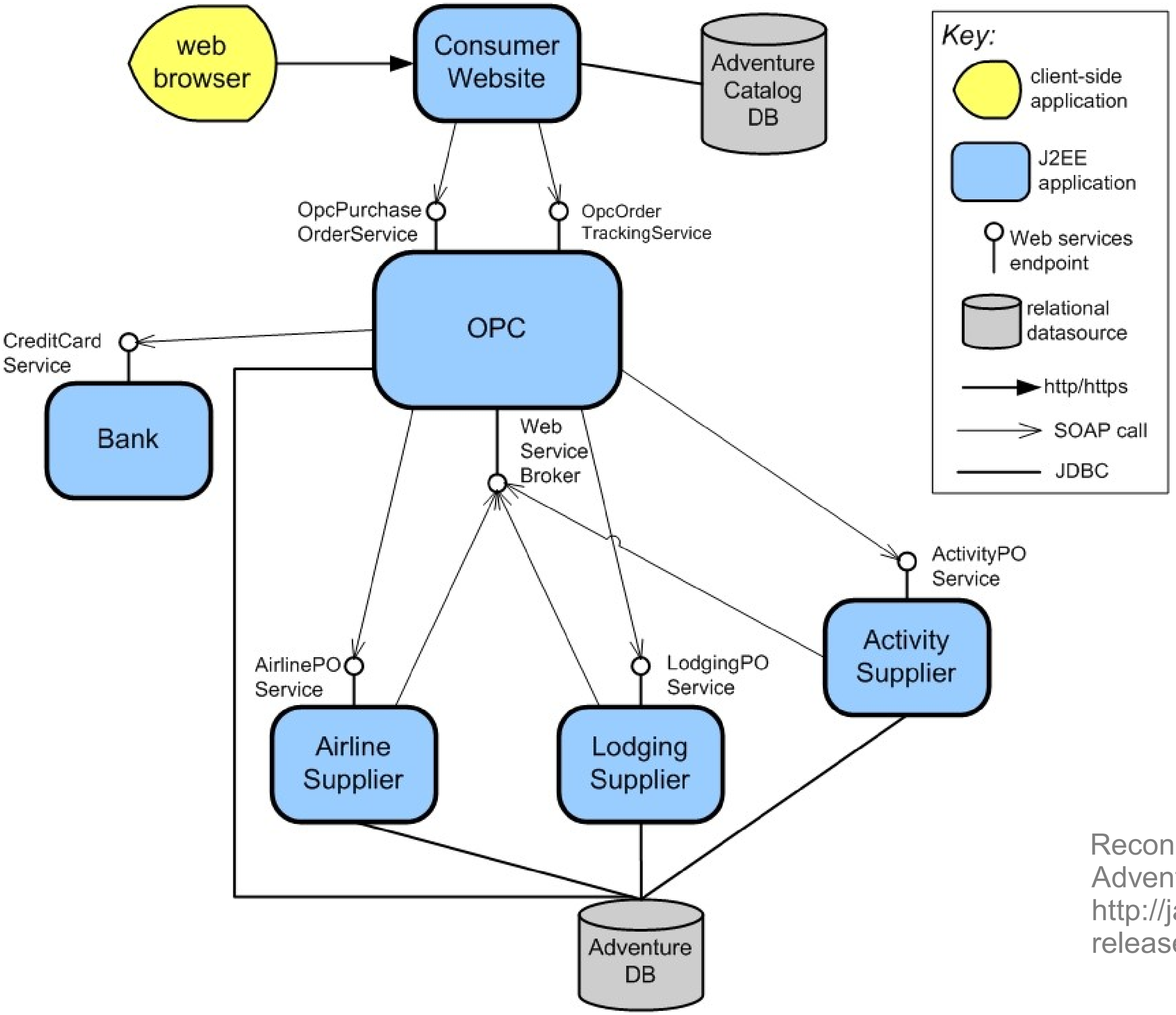
Reconstructed from Duke’s Bank Application—Sun J2EE 1.3 tutorial

Runtime View—Duke’s Bank—Not So Good Example



Original diagram of Duke’s Bank Application from Sun J2EE 1.3 tutorial (with our amendment)
http://java.sun.com/j2ee/tutorial/1_3-fcs/doc/Ebank2.html

Runtime View—Adventure Builder

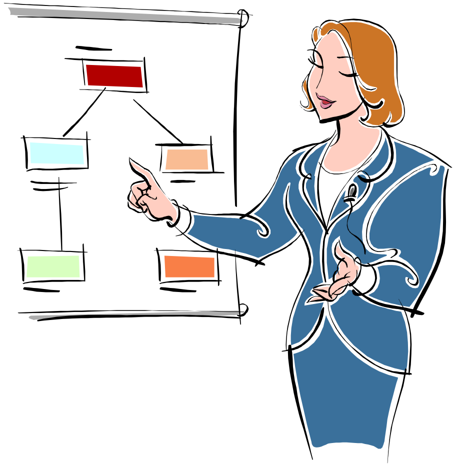


SOA Example

Reconstructed from Adventure Builder Application http://java.sun.com/developer/releases/adventure/

What Are Runtime Views Good For?

- Explaining:
  - How components interact at runtime
  - What components are replicated
  - What components access data stores
- Education—starting point to show how the system works
- Analysis of runtime properties
  - Performance
  - Security
  - Reliability



Agenda

Introduction

Multi-View Architecture

- Module Views
- Runtime Views
- **Deployment Views**
- Data Model

Template for an Architecture Document

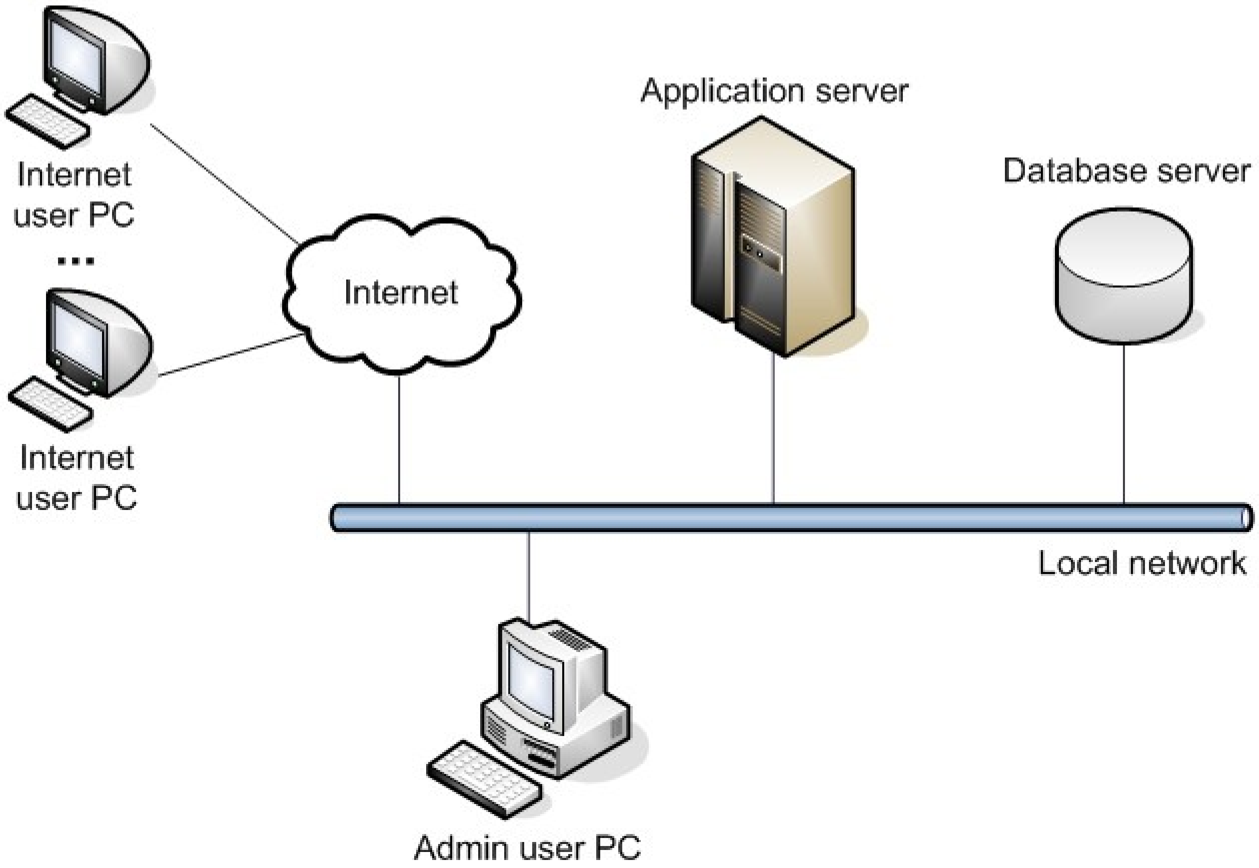
Outroduction

Deployment Views

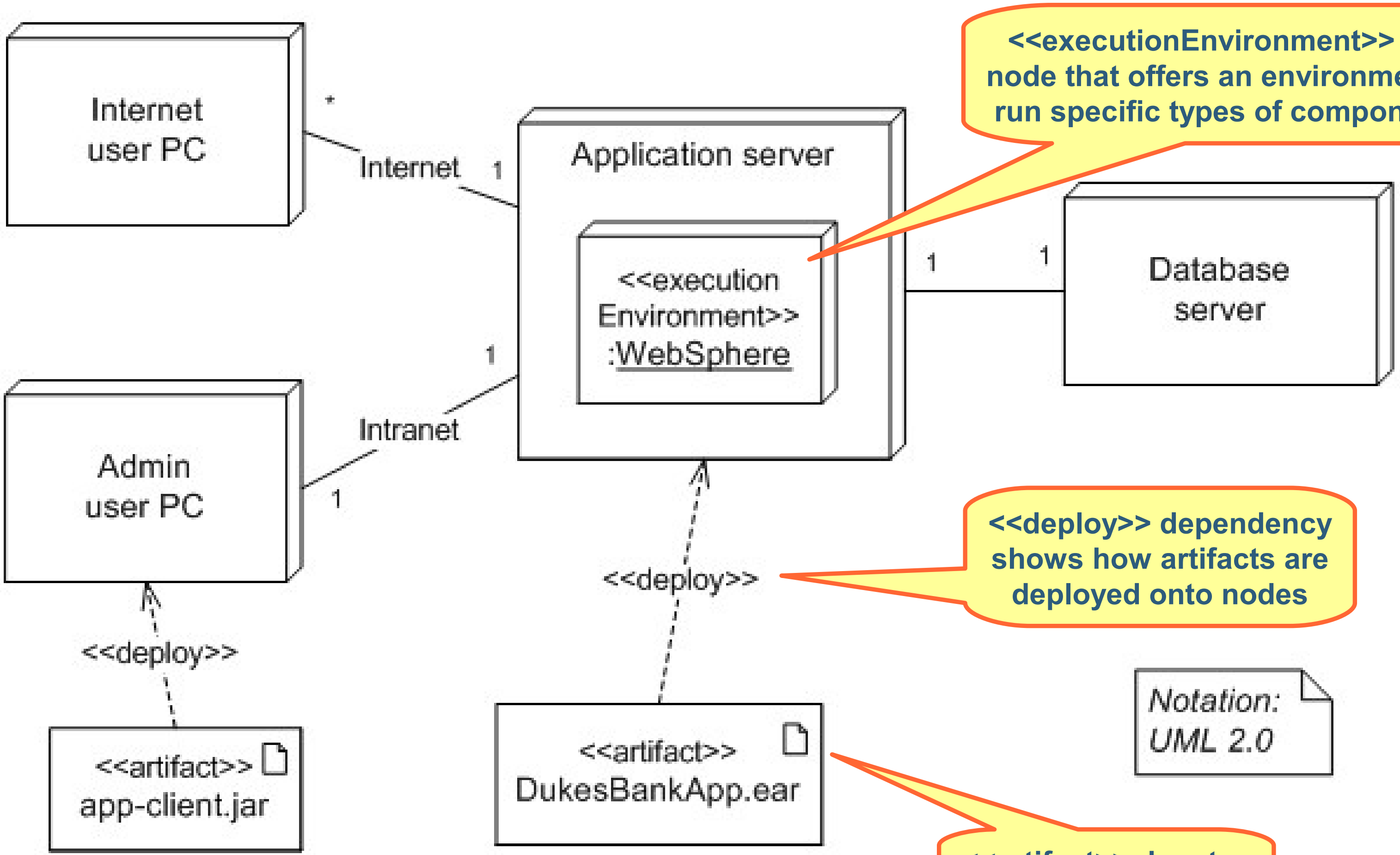
- Show at least two distinct but related structures:
  1. **Hardware** infrastructure of the production environment
  2. Structure of **directories and files** of deployed system
- **Elements**:
  1. Processing and communication nodes (e.g., server machine, router)
  2. Files, directories
- **Relations**:
  1. Interaction mechanisms between two elements are usually communication channels
  2. Containment: a directory/file contains other directories and files

Deployment View—Hardware Infrastructure—Duke's Bank[1]

Informal Notation



Deployment View—Hardware Infrastructure—Duke's Bank(2)



<<executionEnvironment>> is a node that offers an environment to run specific types of components

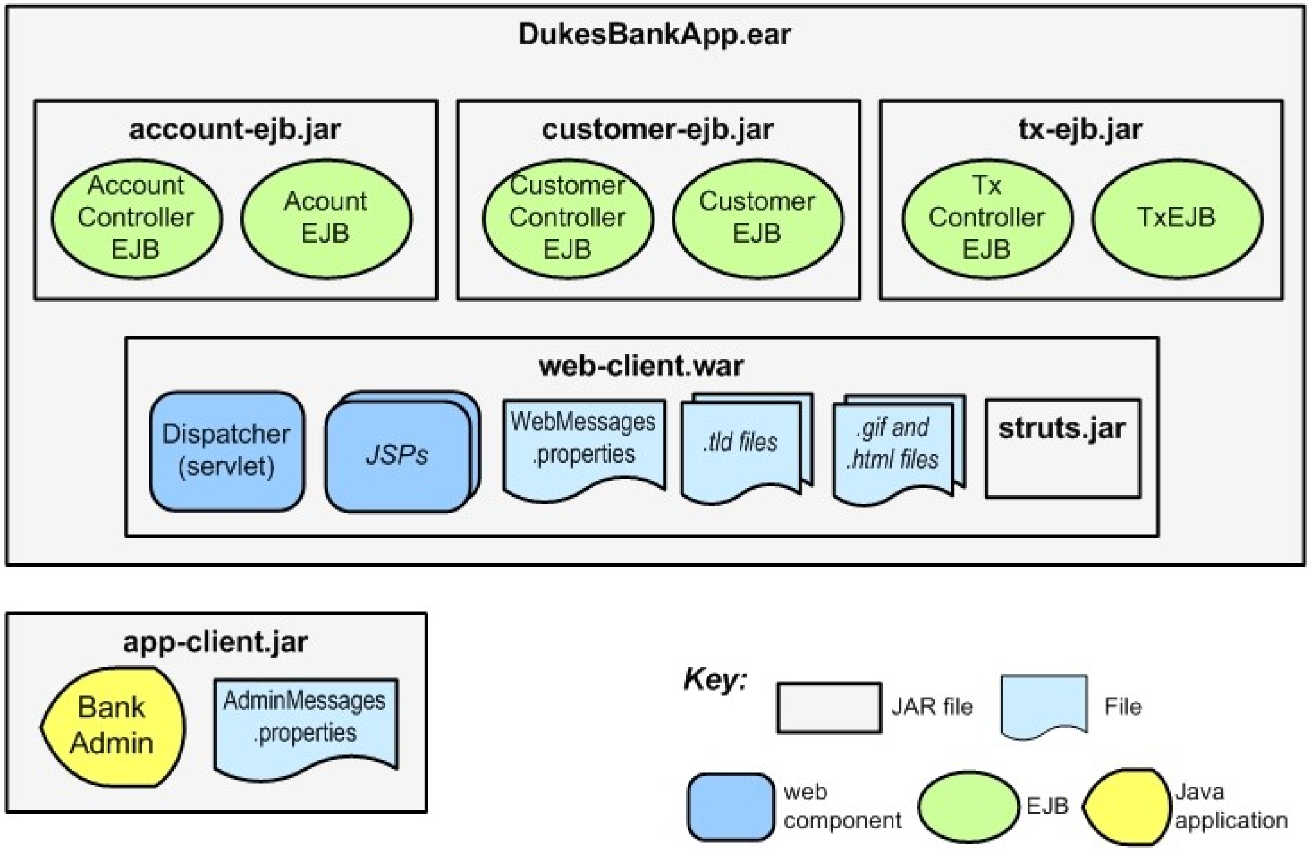
<<deploy>> dependency shows how artifacts are deployed onto nodes

Notation: UML 2.0

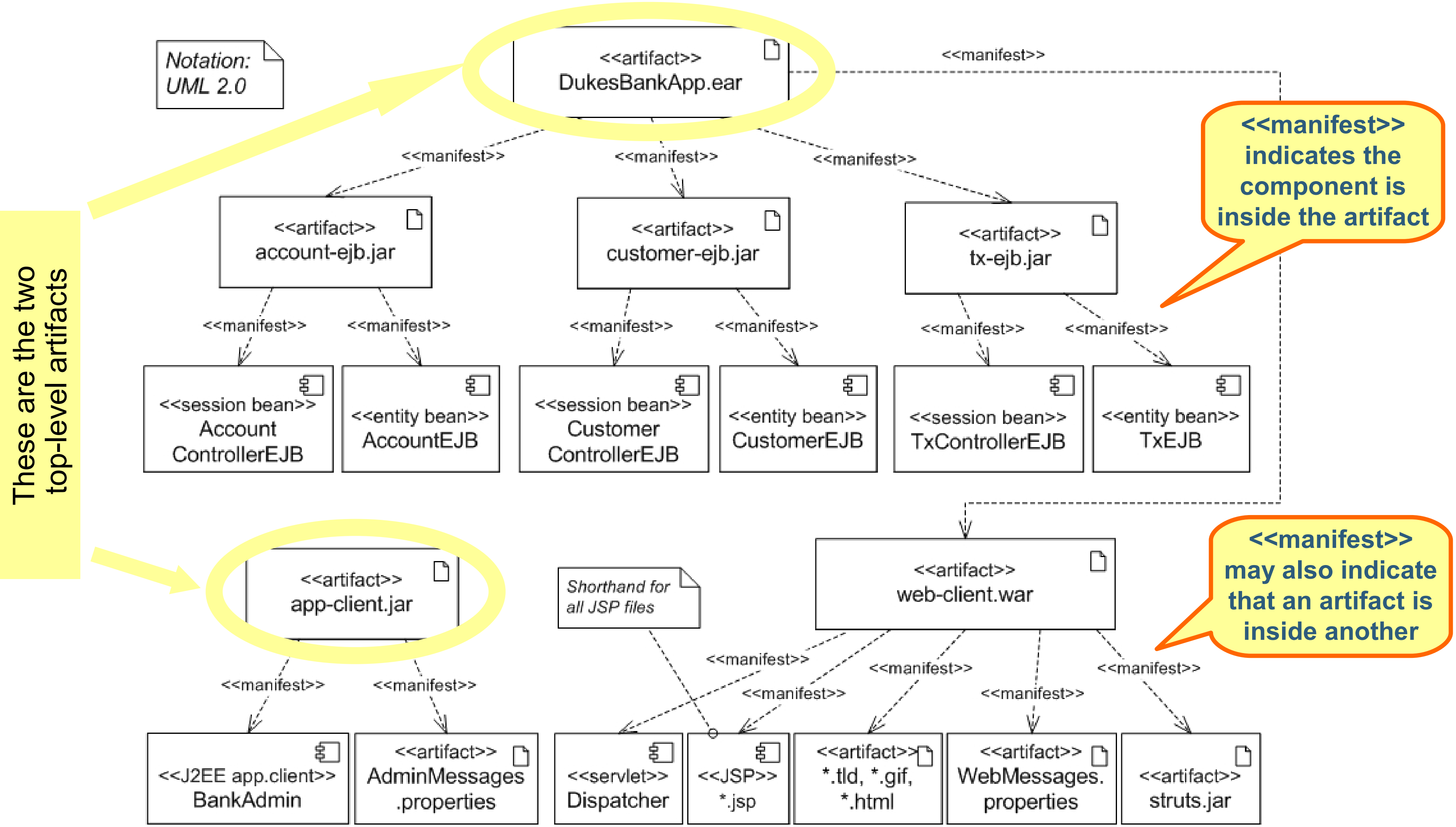
<<artifact>> denotes a file of any kind

Deployment View—Deployment Files —Duke's Bank[1]

Informal Notation



Deployment View—Deployment Files —Duke’s Bank(2)



Notation: UML 2.0
<<artifact>> DukesBankApp.ear
<<manifest>>
<<artifact>> account-ejb.jar
<<artifact>> customer-ejb.jar
<<artifact>> tx-ejb.jar
<<session bean>> Account ControllerEJB
<<entity bean>> AccountEJB
<<session bean>> Customer ControllerEJB
<<entity bean>> CustomerEJB
<<session bean>> TxControllerEJB
<<entity bean>> TxEJB
<<artifact>> app-client.jar
<<J2EE app.client>> BankAdmin
<<artifact>> AdminMessages .properties
Shorthand for all JSP files
<<artifact>> web-client.war
<<servlet>> Dispatcher
<<JSP>> *.jsp
<<artifact>> *.tld, *.gif, *.html
<<artifact>> WebMessages. properties
<<artifact>> struts.jar

These are the two top-level artifacts

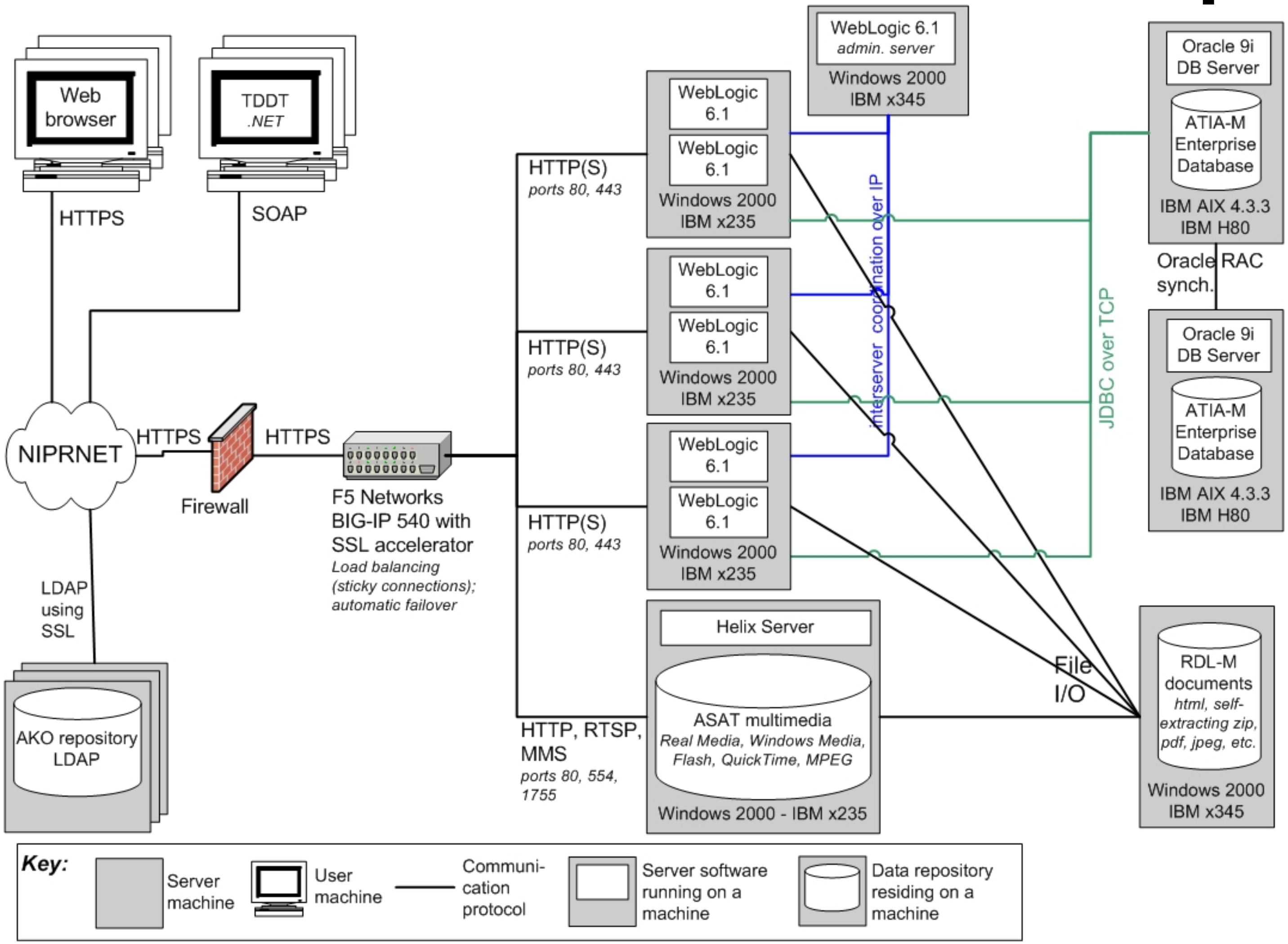
<<manifest>> indicates the component is inside the artifact

<<manifest>> may also indicate that an artifact is inside another

What Are Deployment Views Good For?

- Defining deployment and operation procedures
- Auditing runtime failures
- Planning purchasing options
- Analyzing:
  - Availability
  - Performance (e.g., throughput, bandwidth utilization)
  - Security
  - Reliability
- Education and stakeholder communication

Deployment View—Hardware Infrastructure—Real-World Example



Web browser

TDDT .NET

HTTPS

SOAP

NIPRNET

HTTPS

Firewall

HTTPS

F5 Networks BIG-IP 540 with SSL accelerator

Load balancing (sticky connections); automatic failover

LDAP using SSL

AKO repository LDAP

HTTP(S) *ports 80, 443*

HTTP(S) *ports 80, 443*

HTTP(S) *ports 80, 443*

HTTP, RTSP, MMS *ports 80, 554, 1755*

WebLogic 6.1 / WebLogic 6.1 / Windows 2000 IBM x235

WebLogic 6.1 / WebLogic 6.1 / Windows 2000 IBM x235

WebLogic 6.1 / WebLogic 6.1 / Windows 2000 IBM x235

WebLogic 6.1 *admin. server* / Windows 2000 IBM x345

Interserver coordination over IP

JDBC over TCP

Oracle 9i DB Server / ATIA-M Enterprise Database / IBM AIX 4.3.3 IBM H80

Oracle RAC synch.

Oracle 9i DB Server / ATIA-M Enterprise Database / IBM AIX 4.3.3 IBM H80

Helix Server / ASAT multimedia *Real Media, Windows Media, Flash, QuickTime, MPEG* / Windows 2000 - IBM x235

File I/O

RDL-M documents *html, self-extracting zip, pdf, jpeg, etc.* / Windows 2000 IBM x345

Key: Server machine; User machine; Communi-cation protocol; Server software running on a machine; Data repository residing on a machine

Agenda

Introduction

Multi-View Architecture

- Module Views
- Runtime Views
- Deployment Views
- **Data Model**

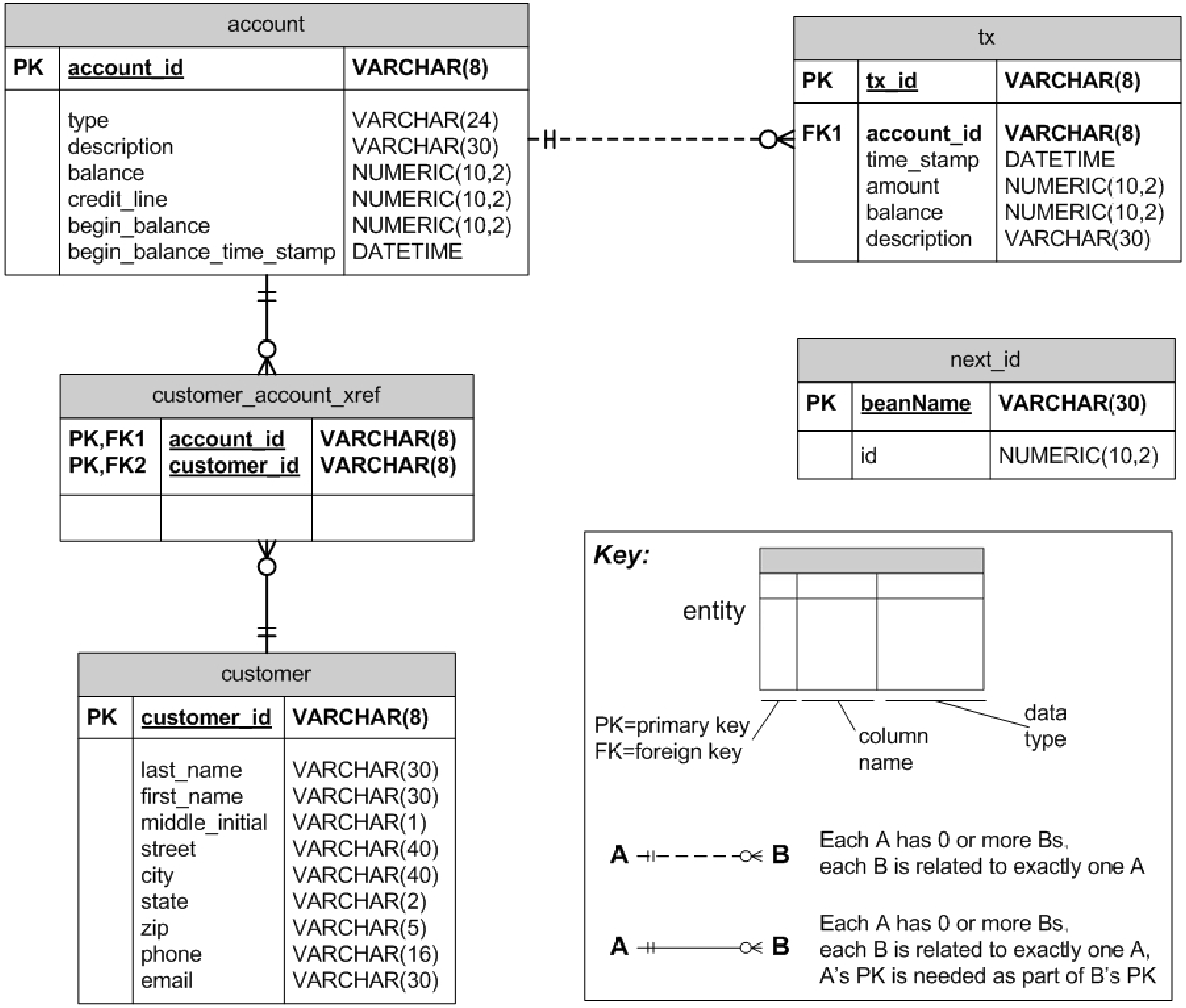
Template for an Architecture Document

Outroduction

Data Model

- Shows structure of the data repository
- **Elements**: entities (persisted domain elements)
- **Relations**:
  - 1:1, 1:n and n:n relationships
  - Generalization/specialization
  - Aggregation

Data Model—Duke's Bank[1]



account		
PK	account_id	VARCHAR(8)
	type	VARCHAR(24)
	description	VARCHAR(30)
	balance	NUMERIC(10,2)
	credit_line	NUMERIC(10,2)
	begin_balance	NUMERIC(10,2)
	begin_balance_time_stamp	DATETIME

tx		
PK	tx_id	VARCHAR(8)
FK1	account_id	VARCHAR(8)
	time_stamp	DATETIME
	amount	NUMERIC(10,2)
	balance	NUMERIC(10,2)
	description	VARCHAR(30)

customer_account_xref		
PK,FK1	account_id	VARCHAR(8)
PK,FK2	customer_id	VARCHAR(8)

next_id		
PK	beanName	VARCHAR(30)
	id	NUMERIC(10,2)

customer		
PK	customer_id	VARCHAR(8)
	last_name	VARCHAR(30)
	first_name	VARCHAR(30)
	middle_initial	VARCHAR(1)
	street	VARCHAR(40)
	city	VARCHAR(40)
	state	VARCHAR(2)
	zip	VARCHAR(5)
	phone	VARCHAR(16)
	email	VARCHAR(30)

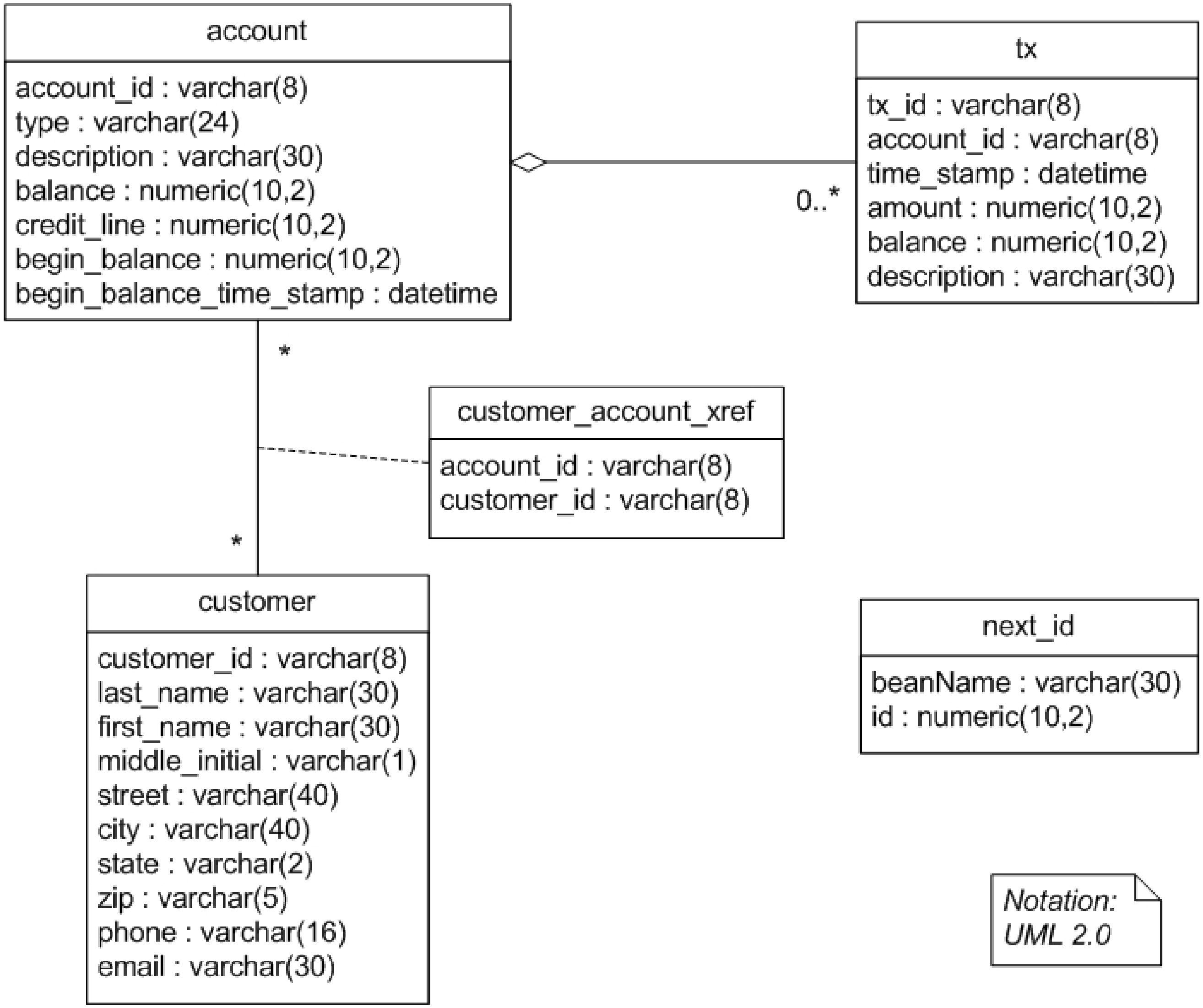
Key:

Each A has 0 or more Bs,
each B is related to exactly one A

Each A has 0 or more Bs,
each B is related to exactly one A,
A's PK is needed as part of B's PK

ERD Notation

Data Model—Duke’s Bank(2)



account

account_id : varchar(8)
type : varchar(24)
description : varchar(30)
balance : numeric(10,2)
credit_line : numeric(10,2)
begin_balance : numeric(10,2)
begin_balance_time_stamp : datetime

tx

tx_id : varchar(8)
account_id : varchar(8)
time_stamp : datetime
amount : numeric(10,2)
balance : numeric(10,2)
description : varchar(30)

customer_account_xref

account_id : varchar(8)
customer_id : varchar(8)

customer

customer_id : varchar(8)
last_name : varchar(30)
first_name : varchar(30)
middle_initial : varchar(1)
street : varchar(40)
city : varchar(40)
state : varchar(2)
zip : varchar(5)
phone : varchar(16)
email : varchar(30)

next_id

beanName : varchar(30)
id : numeric(10,2)

Notation:
UML 2.0

What Is the Data Model Good For?

- Blueprint for physical database
- Reference to all programs that manipulate data items
- Database tuning (e.g., via normalization):
    - For better performance and modifiability
    - To avoid redundancy
    - To enforce consistency

Agenda

Introduction

Multi-View Architecture

- Module Views
- Runtime Views
- Deployment Views
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Template for an Architecture Document

Outroduction

Software Architecture Documentation

- How do we document a view?
- How do we document everything else beyond the views?

Documenting a View(1)

1. Primary presentation

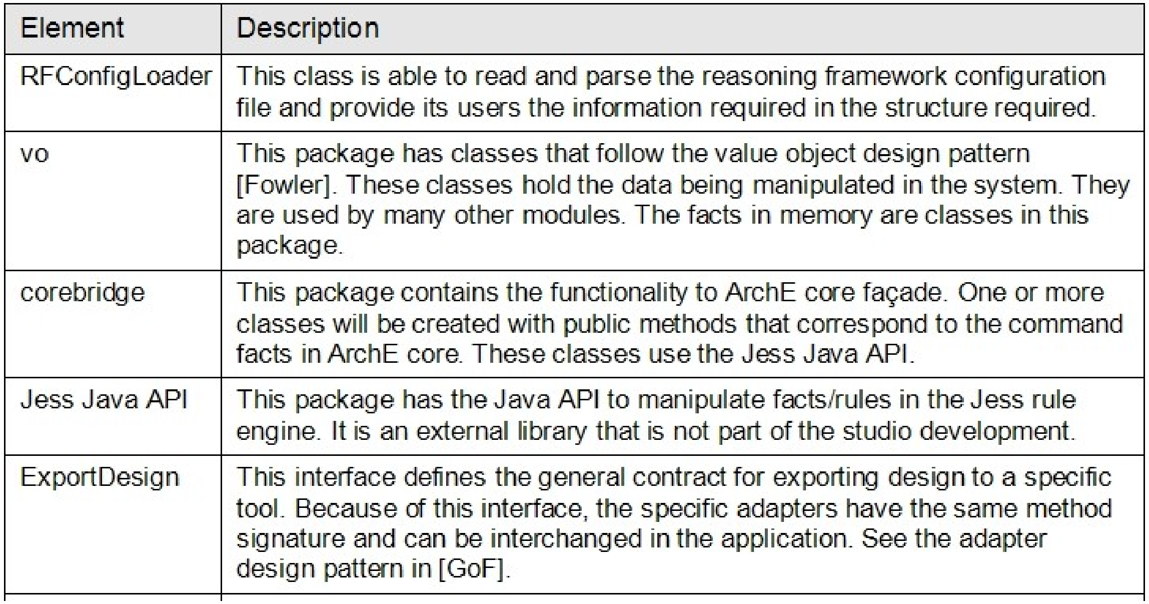
- Is usually graphical
- Shows elements and relations among them
- Should include a key that explains the notation
  - Give meaning of each symbol; don’t forget the lines!

Many Times, the Primary Presentation Is All You Get. It’s Not Enough!

Documenting a View(2)

2. Element catalog

- Explains elements depicted in primary presentation
- Is usually a table with element name and textual description



Element	Description
RFConfigLoader	This class is able to read and parse the reasoning framework configuration file and provide its users the information required in the structure required.
vo	This package has classes that follow the value object design pattern [Fowler]. These classes hold the data being manipulated in the system. They are used by many other modules. The facts in memory are classes in this package.
corebridge	This package contains the functionality to ArchE core façade. One or more classes will be created with public methods that correspond to the command facts in ArchE core. These classes use the Jess Java API.
Jess Java API	This package has the Java API to manipulate facts/rules in the Jess rule engine. It is an external library that is not part of the studio development.
ExportDesign	This interface defines the general contract for exporting design to a specific tool. Because of this interface, the specific adapters have the same method signature and can be interchanged in the application. See the adapter design pattern in [GoF].

Documenting a View(3)

3. Variability guide

- Identify points where system can be configured
  - Number of instances in a pool
  - Optional inclusion of components (plug-ins, add-ons)
  - Selection among different implementations of a component or connector
  - Parameterized values set at build, deploy or run-time

Documenting a View(4)

4. Architecture background

- Rationale for design decisions (including relevant rejected alternatives)
- Results of analysis, prototypes, and experiments
- Assumptions and constraints affecting this view

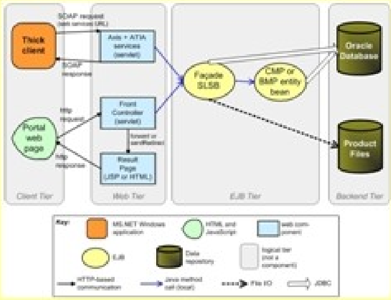
5. Related views

- Pointer to parent view or children views

Outline of a Documented View

Template for a View

1. Primary Presentation



2. Element Catalog

Element	Description
Thick client	Represents a MS .NET windows application developed using C# that communicates with the server-side components via web services (SOAP)
Portal web page	TODO
Axis + ATIA services (servlet)	This component represents the Apache Axis SOAP engine, which runs as a servlet. The Axis servlet takes http requests that point to a URL that is a web service. These http requests are actually SOAP requests. In addition to the Axis servlet, there are two other servlets used by Axis (not depicted). Thus, at runtime Axis consists of three core web components: ▪ AxisServlet – main servlet responsible for dispatching requests (org.apache.axis.transport.http.AxisServlet) ▪ AdminServlet – serves the Administration client application (org.apache.axis.transport.http.AdminServlet) ▪ SOAPMonitorService – monitor service (org.apache.axis.monitor.SOAPMonitorService)
Façade SLSB	A stateless session bean that implements "business logic" functionality. Some façade session beans access the database directly (using DAO classes) and others use entity beans.
Product Files	Static content files stored in the file system. Include pdf files, images, audio and movies.

3. Variability Guide
4. Architecture Background
    4.1 Design Rationale
    4.2 Results of Analysis and Experiments
    4.3 Assumptions and Constraints
5. Related Views

Software Architecture Document[(1)]

1. Documentation roadmap

- Shows how documentation is organized
- Has reference to template used
- Includes scenarios for using the documentation

2. System overview

- Description of the system and its purpose
- Context diagram to show scope
- May point to overview elsewhere in the overall system documentation

Software Architecture Document$^{(2)}$

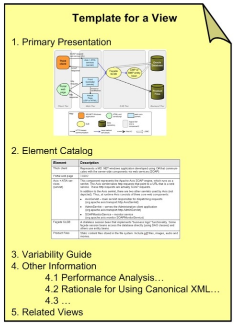
3. Requirements

- May point to separate requirements document
- Three kinds of requirements are relevant to the architecture:
    - Functional requirements (usually captured as use cases)
    - Quality attribute requirements (performance, availability, etc.)
    - Design constraints; example: “the system shall use Hibernate for persistence”

Software Architecture Document(3)

4. Views

- 4.1



Template for a View

1. Primary Presentation

Portal web page
Result Page (JSP or HTML)
Product Files
Client Tier
Web Tier
EJB Tier
Backend Tier
Key:
MS.NET Windows application
HTML and JavaScript
web component
EJB
Data repository
logical tier (not a component)
HTTP-based communication
Java method call (local)
File I/O
JDBC

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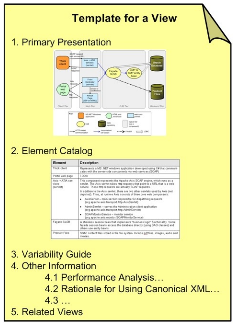
Façade SLSB	A stateless session bean that implements "business logic" functionality. Some façade session beans access the database directly (using DAO classes) and others use entity beans.
Product Files	Static content files stored in the file system. Include pdf files, images, audio and movies.

3. Variability Guide
4. Other Information
    4.1 Performance Analysis…
    4.2 Rationale for Using Canonical XML…
    4.3 …
5. Related Views

- 4.2



Template for a View

1. Primary Presentation

2. Element Catalog

Element	Description
Thick client	Represents a MS .NET windows application developed using C# that communicates with the server-side components via web services (SOAP)
Portal web page	TODO
Axis + ATIA services (servlet)	This component represents the Apache Axis SOAP engine, which runs as a servlet. The Axis servlet takes http requests that point to a URL that is a web service. These http requests are actually SOAP requests. In addition to the Axis servlet, there are two other servlets used by Axis (not depicted). Thus, at runtime Axis consists of three core web components: • AxisServlet – main servlet responsible for dispatching requests (org.apache.axis.transport.http.AxisServlet) • AdminServlet – serves the Administration client application (org.apache.axis.transport.http.AdminServlet) • SOAPMonitorService – monitor service (org.apache.axis.monitor.SOAPMonitorService)
Façade SLSB	A stateless session bean that implements "business logic" functionality. Some façade session beans access the database directly (using DAO classes) and others use entity beans.
Product Files	Static content files stored in the file system. Include pdf files, images, audio and movies.

3. Variability Guide
4. Other Information
    4.1 Performance Analysis…
    4.2 Rationale for Using Canonical XML…
    4.3 …
5. Related Views

- 4.3

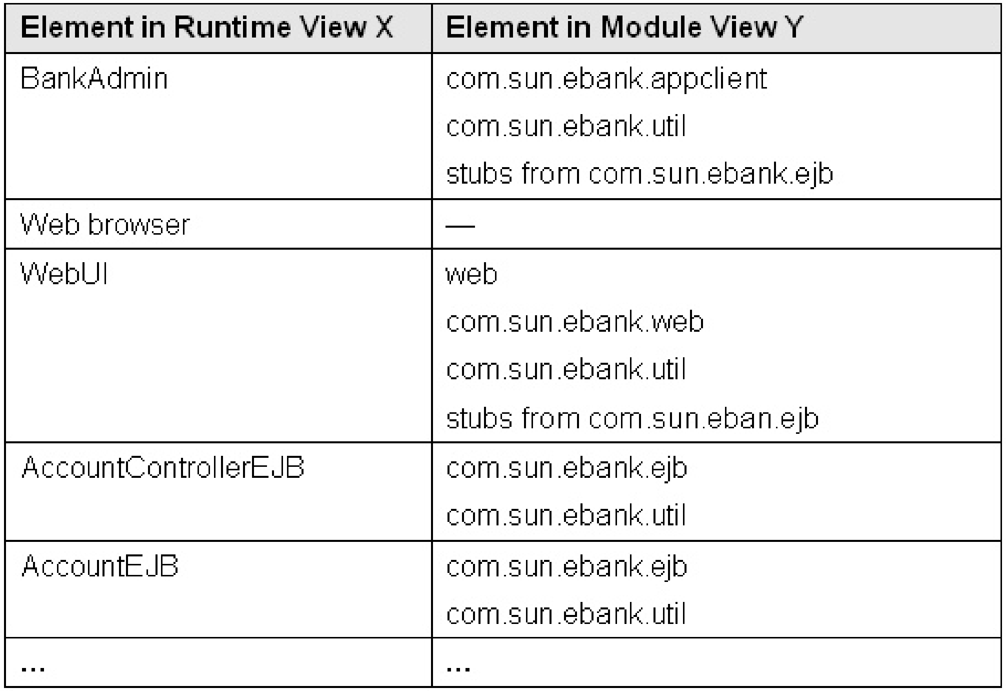
…

Software Architecture Document$^{(4)}$

5. Mapping between views

- Tables showing how elements in one view map to elements in another view

Only Relevant Mappings Are Documented



Element in Runtime View X	Element in Module View Y
BankAdmin	com.sun.ebank.appclient com.sun.ebank.util stubs from com.sun.ebank.ejb
Web browser	—
WebUI	web com.sun.ebank.web com.sun.ebank.util stubs from com.sun.eban.ejb
AccountControllerEJB	com.sun.ebank.ejb com.sun.ebank.util
AccountEJB	com.sun.ebank.ejb com.sun.ebank.util
...	...

Example From Duke's Bank

Software Architecture Document(5)

6. Architecture analysis and rationale

- Rationale for cross-view design decisions (including rejected alternatives)
- Results of architecture evaluation (e.g., ATAM report)

7. Mapping requirements to architecture

- Shows how each requirement is satisfied by one or more elements of the architecture, or an architectural approach

8. Glossary and acronym list

- May point to a larger glossary elsewhere

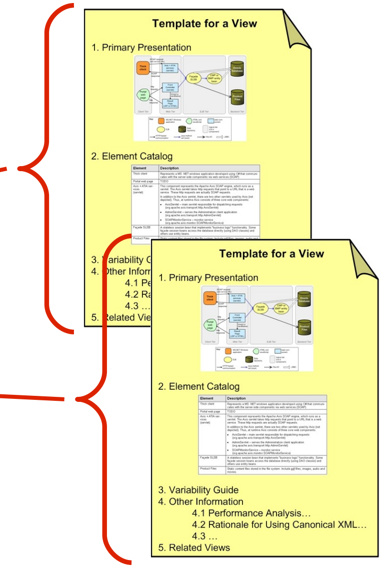
Outline of Software Architecture Document

Template for Software Architecture Document

1. Documentation Roadmap
2. System Overview
3. Requirements
4. Views
   - 4.1 View X
   - 4.2 View Y
   - etc.
5. Mapping Between Views
   - 5.1 Mapping View X to View Y
   - 5.2 Mapping View Y to View Z
   - etc.
6. Architecture Analysis and Rationale
7. Mapping Architecture to Requirements

Use Case	Architecture Solution and Architecture Notes
Create project	Project is an inherent abstraction in Eclipse and so is the navigator view. "Garage Door System" would be a project. For each project, a completely independent instance of "Jess rule engine (ArchE core)" is created. All the data for a given project is stored in "Persisted fact base (.txt)" in. There is one such file per project. Also, the exported design (".xml file" in) is one per project. There will be a user command to create a project triggered by a menu option, which will activate a specific action handler. This action handler will open the New ArchE Project dialog box, which is one of the dialog boxes also.
CRUD functions	The description for CRUD scenarios (above) applies here. The difference is that there is no dialog box specific to add/edit functions or function responsibility mappings.
CRUD responsibilities	The description for CRUD scenarios (above) applies here. The difference is that there is no dialog box specific to add/edit responsibilities.
Export design	There is an action handler that process this user command. It uses the Save File As dialog box to ask for the name of the file. Then it calls "Design export", which creates the "exported design" file. The external design tool is activated manually.

8. Glossary and Acronym List



Template for a View

1. Primary Presentation

2. Element Catalog

3. Variability Guide

4. Other Information

4.1 Performance Analysis…

4.2 Rationale for Using Canonical XML…

4.3 …

5. Related Views

Agenda

Introduction

Multi-View Architecture

- Module Views
- Runtime Views
- Deployment Views
- Data Model

Template for an Architecture Document

Outroduction

What Else Is Important?

- Document behavior using, for example:
  - Sequence diagrams for interesting* traces
  - Statecharts for things that have interesting* states
- Document interfaces beyond syntax
- Indicate what patterns you're using
- Select views to document based on stakeholders' needs

*Interesting = important and/or complex

Summary

- Important takeaways:
  - Describe the architecture in multiple views
    - Module views
    - Runtime views
    - Deployment views
    - Data Model
  - Documentation should not appeal to reader’s intuition
    - Always use a key or indicate the diagram notation
  - Follow a template
  - UML is not always the best notation

For More Information

- www.sei.cmu.edu/architecture
- "Documenting Software Architectures: Views and Beyond" by Paul Clements, et al.
- UML 2.0 Superstructure Specification (www.uml.org)
- http://la.sei.cmu.edu/sad-wiki (for an example)

Or talk to This guy

Q&A

Paulo Merson
pfm@sei.cmu.edu

Suggestions:

- What's the difference between architecture and detailed design?
- I use an Agile process. Should I care about this stuff?
- What if I follow RUP? What about the 4+1 views?
- Hey SEI guy, aren't you gonna talk about CMM?
- Where's the recipe for the Brazilian drink "caipirinha"?

Carnegie Mellon University
Software Engineering Institute

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