UNIVERSITÄT
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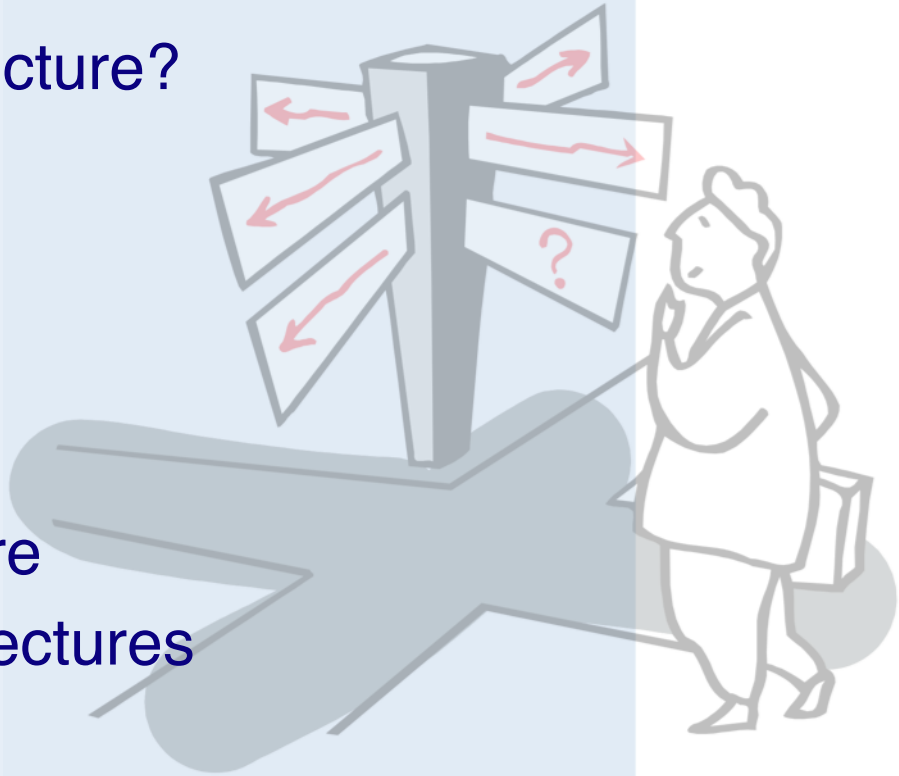
ESE
Einführung in Software Engineering

10. Software Architecture

Prof. O. Nierstrasz

Roadmap

- What is Software Architecture?
- Coupling and Cohesion
- Architectural styles:
  - Layered
  - Client-Server
  - Blackboard, Dataflow, ...
- Model-Driven Architecture
- UML diagrams for architectures



Sources

- *Software Engineering*, I. Sommerville, 7th Edn., 2004.
- *Objects, Components and Frameworks with UML*, D. D'Souza, A. Wills, Addison-Wesley, 1999
- *Pattern-Oriented Software Architecture — A System of Patterns*, F. Buschmann, et al., John Wiley, 1996
- *Software Architecture: Perspectives on an Emerging Discipline*, M. Shaw, D. Garlan, Prentice-Hall, 1996

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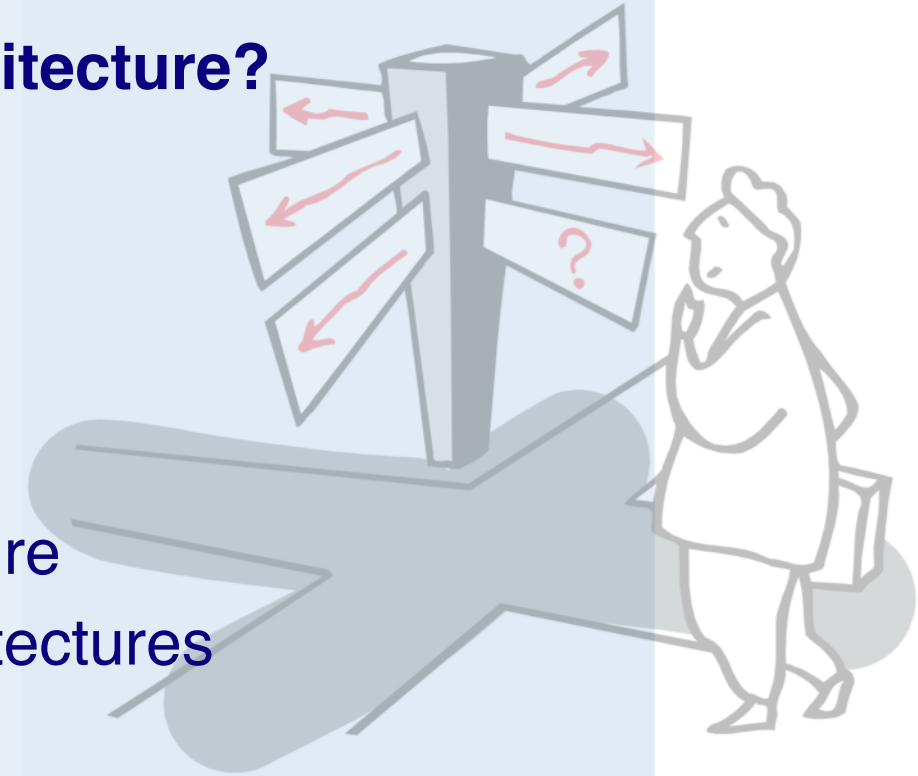

What is Software Architecture?

A neat-looking drawing of some boxes, circles, and lines, laid out nicely in Powerpoint or Word, does not constitute an architecture.

— D'Souza & Wills

What is Software Architecture?

The architecture of a system consists of:

- the *structure(s) of its parts*
  - —including design-time, test-time, and run-time hardware and software parts
- the *externally visible properties* of those parts
  - —modules with interfaces, hardware units, objects
- the *relationships and constraints* between them

in other words:

The set of *design decisions* about any system (or subsystem) that keeps its implementors and maintainers from exercising *"needless creativity"*.

How Architecture Drives Implementation

- Use a *3-tier client-server architecture*: all business logic must be in the middle tier, presentation and dialogue on the client, and data services on the server; that way you can scale the application server processing independently of persistent store.

- Use *Corba* for all distribution, using Corba event channels for notification and the Corba relationship service; do not use the Corba messaging service as it is not yet mature.

How Architecture Drives Implementation ...

- Use Collection Galore's *collections* for representing any collections; by default use their List class, or document your reason otherwise.

- Use *Model-View-Controller* with an explicit `ApplicationModel` object to connect any UI to the business logic and objects.

Sub-systems, Modules and Components

- A sub-system is a system in its own right whose operation is *independent* of the services provided by other sub-systems.

- A module is a system component that *provides services* to other components but would not normally be considered as a separate system.

- A component is an *independently deliverable unit* of software that encapsulates its design and implementation and offers interfaces to the out-side, by which it may be composed with other components to form a larger whole.

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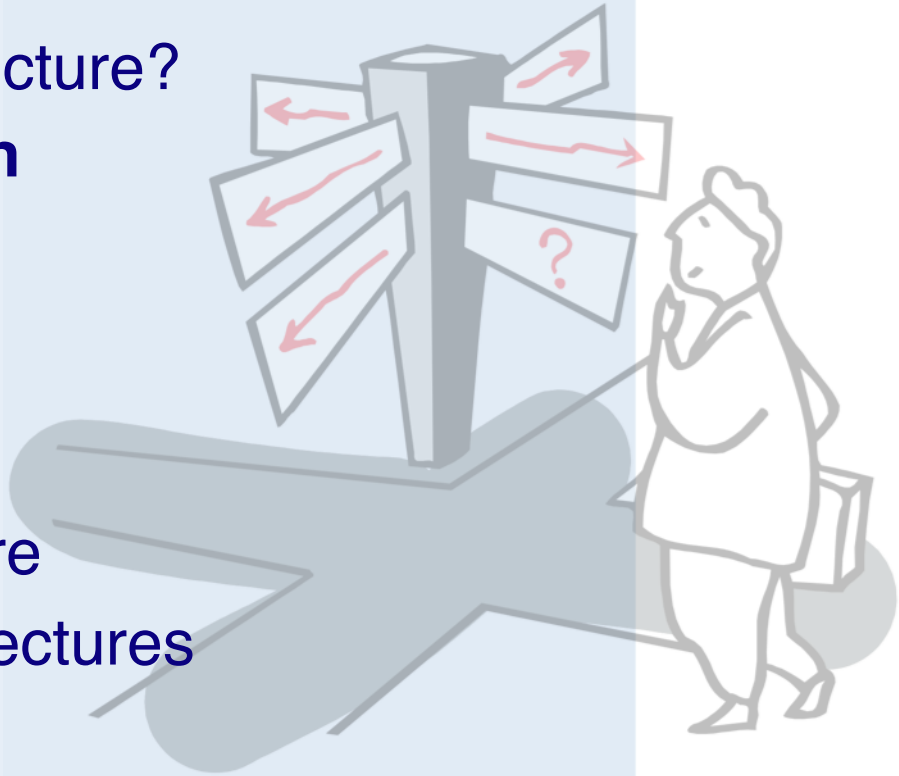


Cohesion

Cohesion is a measure of *how well the parts of a component "belong together".*

- Cohesion is weak if elements are bundled simply because they perform similar or related functions (e.g., `java.lang.Math`).
- Cohesion is strong if all parts are needed for the functioning of other parts (e.g. `java.lang.String`).
  - Strong cohesion *promotes maintainability* and adaptability by *limiting the scope of changes* to small numbers of components.

There are many definitions and interpretations of cohesion.

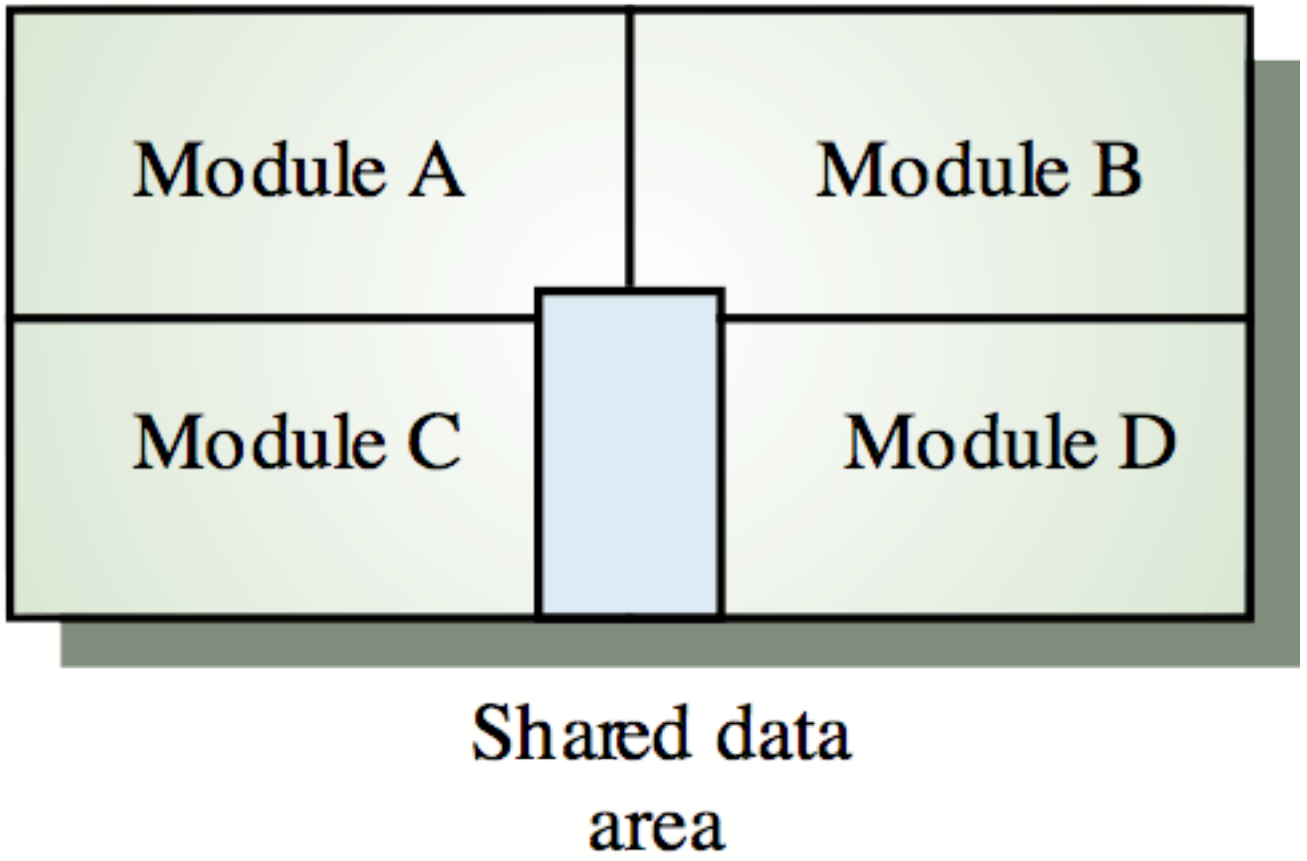
Most attempts to formally define it are inadequate!

Coupling

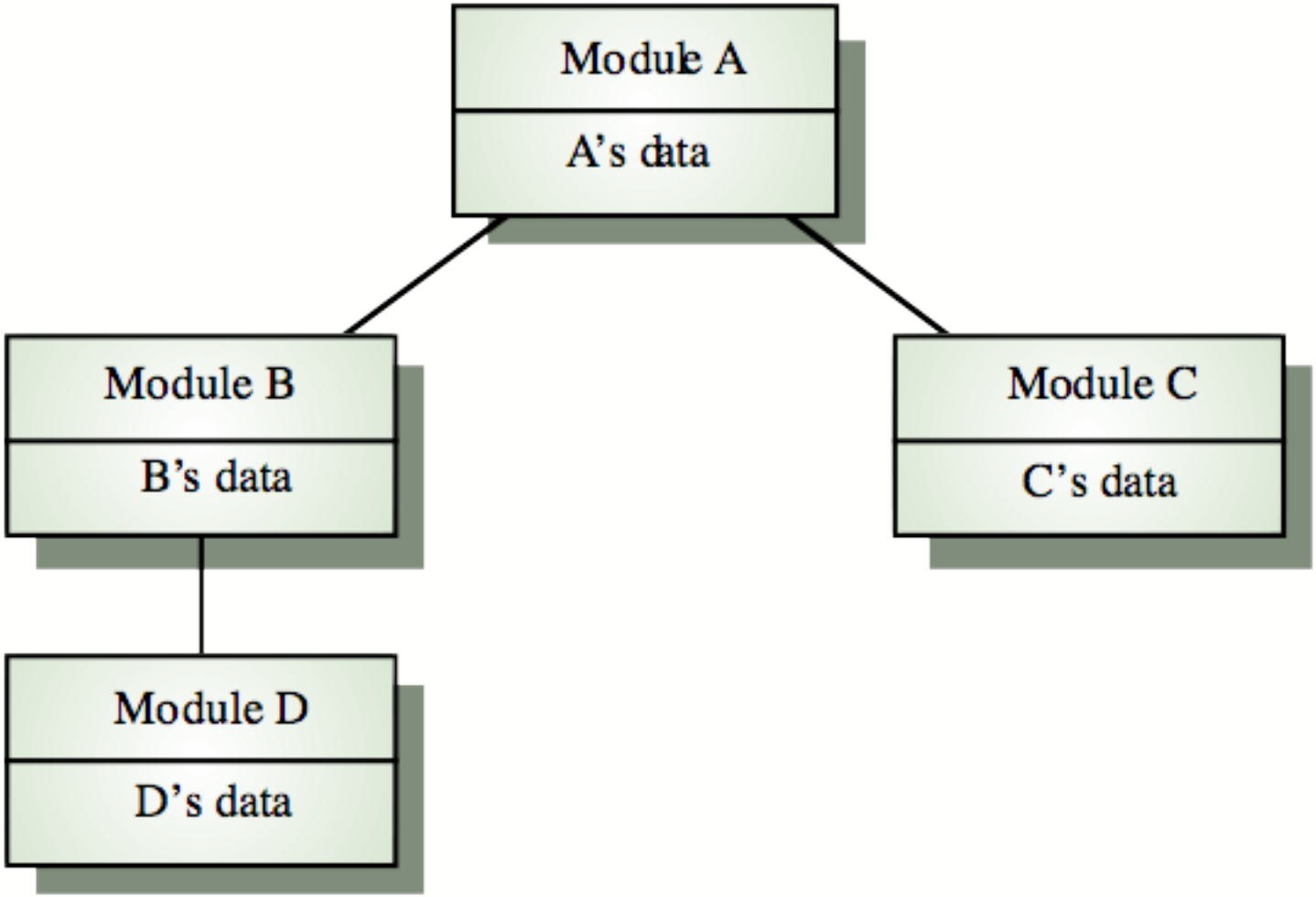
Coupling is a measure of the *strength of the interconnections* between system components.

- Coupling is tight between components if they depend heavily on one another, (e.g., there is a lot of communication between them).
- Coupling is loose if there are few dependencies between components.
  - Loose coupling *promotes maintainability* and adaptability since *changes in one component are less likely to affect others.*

Tight Coupling



Loose Coupling



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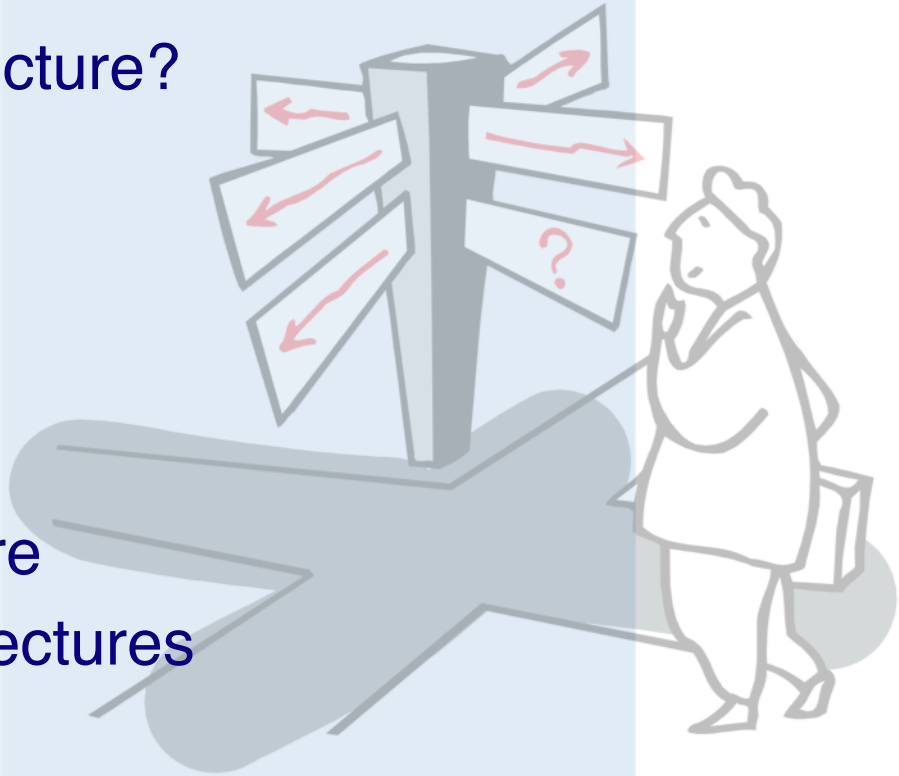

Architectural Parallels

- Architects are the *technical interface* between the customer and the contractor building the system
- A bad architectural design for a building *cannot be rescued by good construction* — the same is true for software
- There are *specialized types* of building and software architects
- There are *schools or styles* of building and software architecture

Architectural Styles

An architectural style defines a family of systems in terms of a pattern of structural organization. More specifically, an architectural style defines a vocabulary of components and connector types, and a set of constraints on how they can be combined.

— Shaw and Garlan

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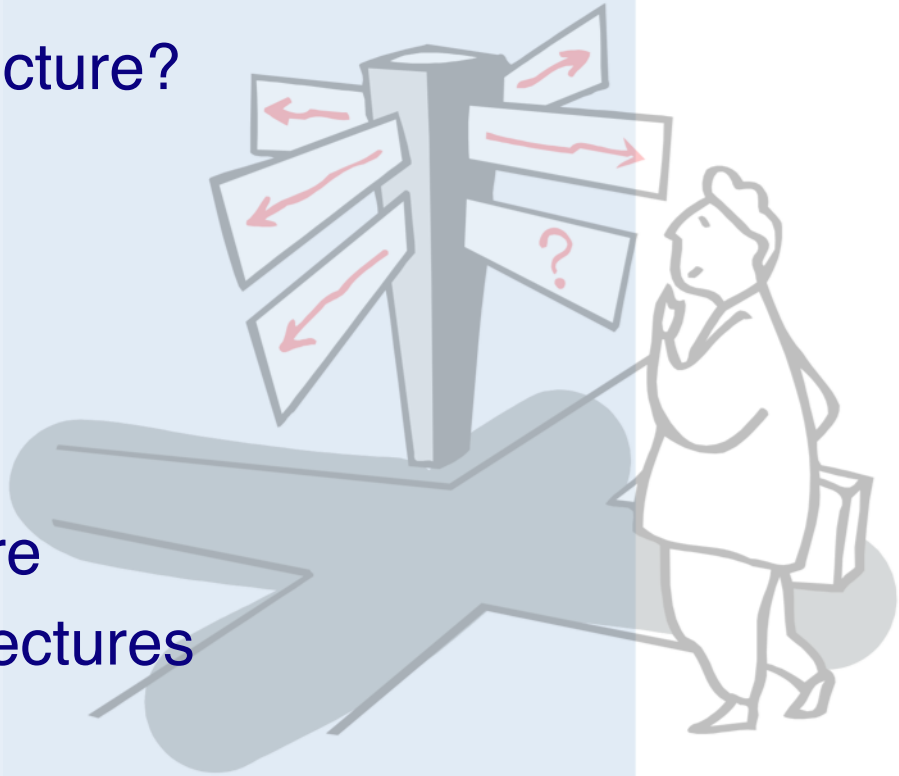
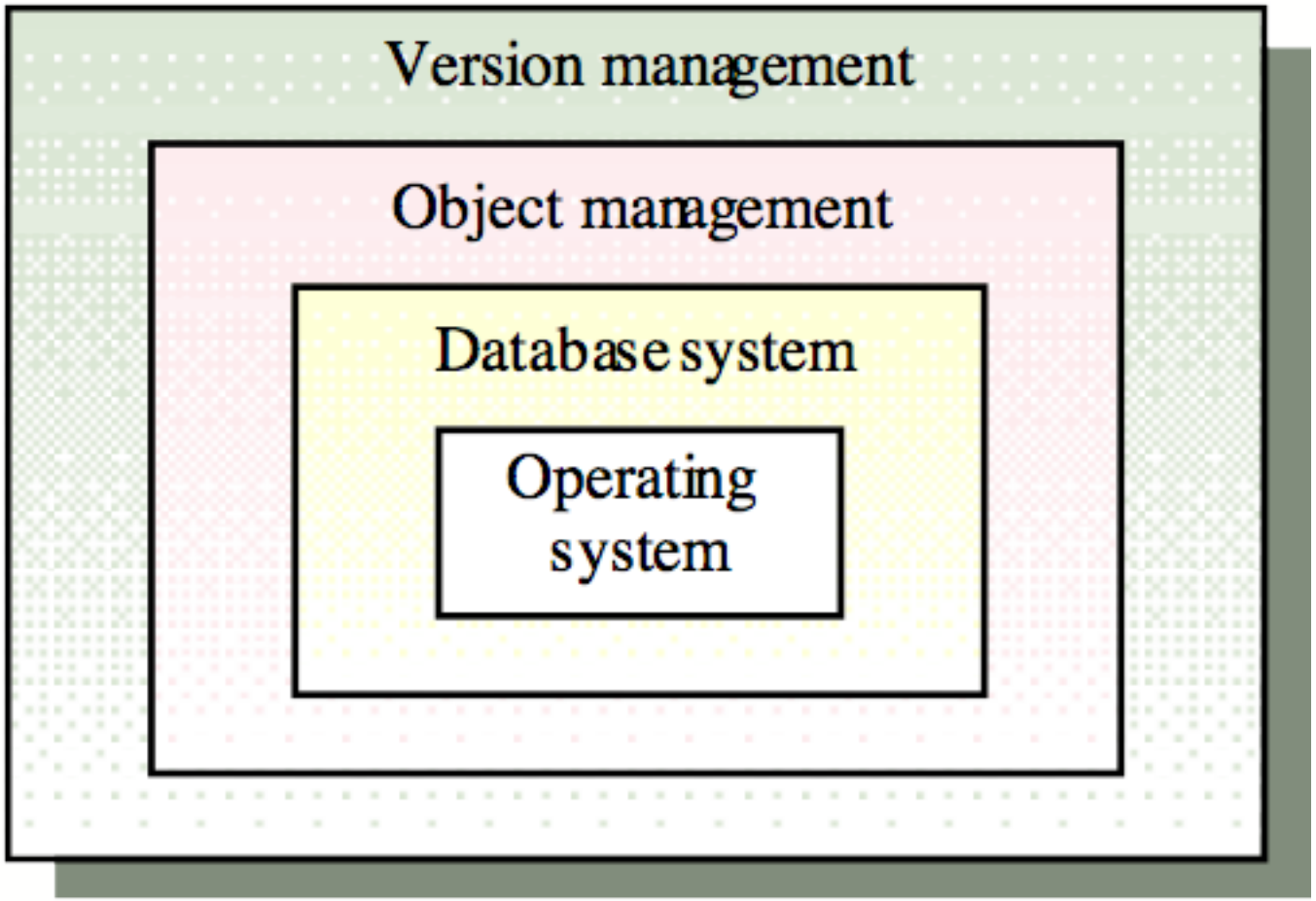


Layered Architectures

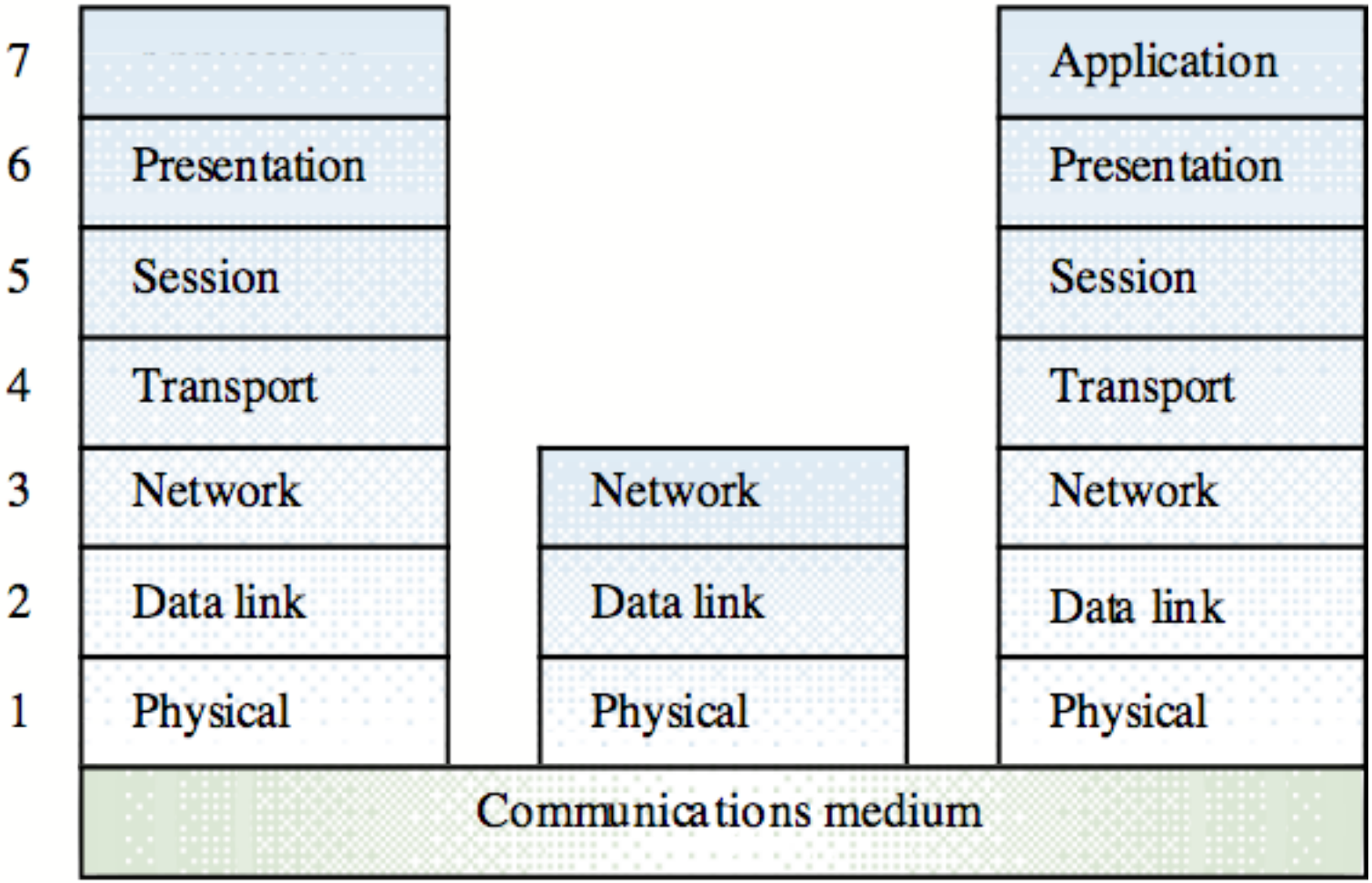
A layered architecture organises a system into a set of layers each of which provide a set of services to the layer "above".

- Normally layers are *constrained* so elements only see
  - other elements in the same layer, or
  - elements of the layer below
- *Callbacks* may be used to communicate to higher layers
- Supports the *incremental development* of sub-systems in different layers.
  - When a layer interface changes, *only the adjacent layer is affected*

Version management system



OSI reference model



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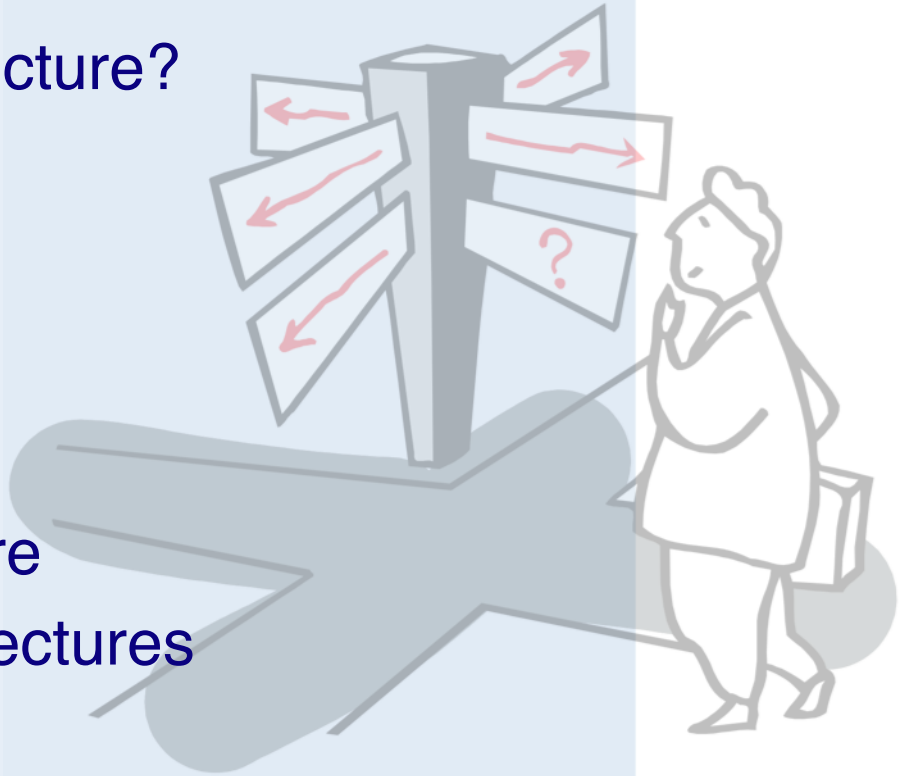


Client-Server Architectures

A client-server architecture *distributes application logic and services* respectively to a number of client and server sub-systems, each potentially running on a different machine and communicating through the network (e.g, by RPC).

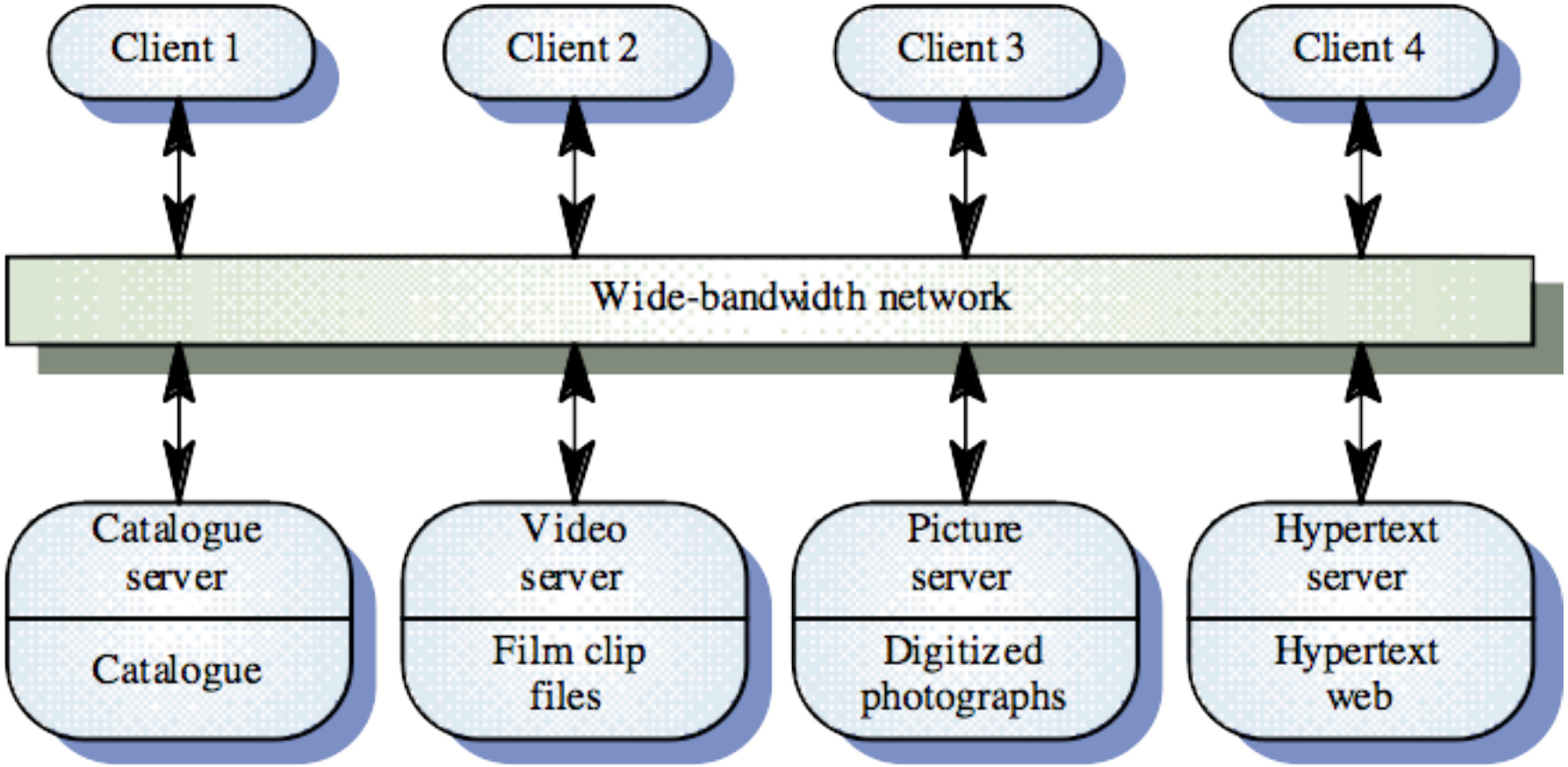
Advantages

- *Distribution* of data is straightforward
- Makes *effective use of networked systems*. May require cheaper hardware
- Easy to *add new servers* or upgrade existing servers

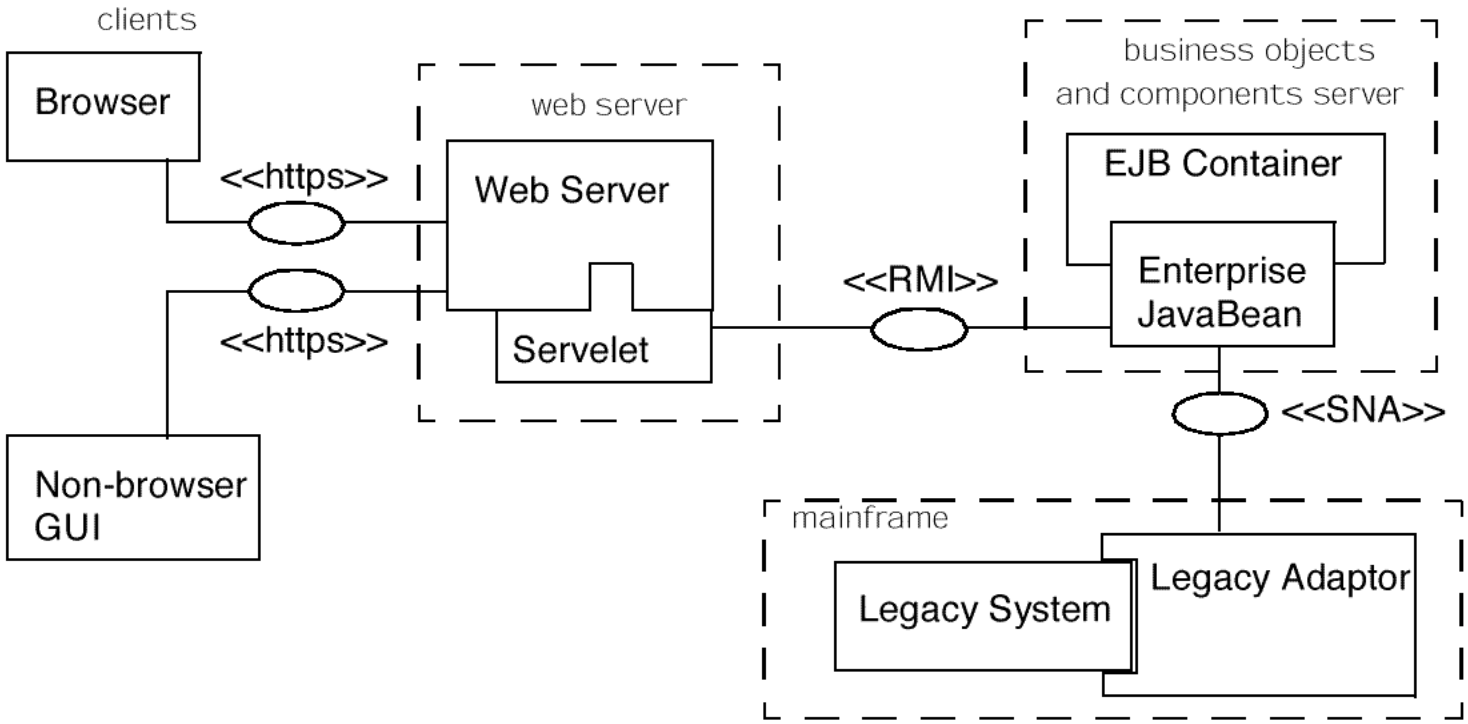
Disadvantages

- *No shared data model* so sub-systems use different data organisation. Data interchange may be inefficient
- *Redundant management* in each server
- May require a *central registry* of names and services — it may be hard to find out what servers and services are available

Film and picture library



Four-Tier Architectures



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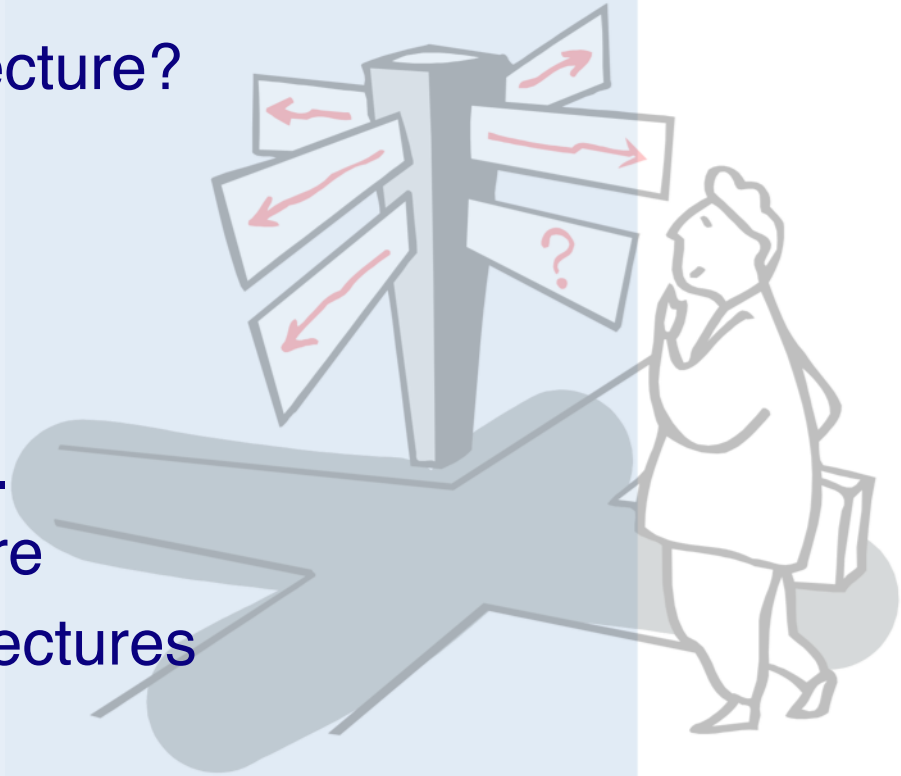


Blackboard Architectures

A blackboard architecture distributes application logic to a number of independent sub-systems, but *manages all data in a single, shared repository* (or “blackboard”).

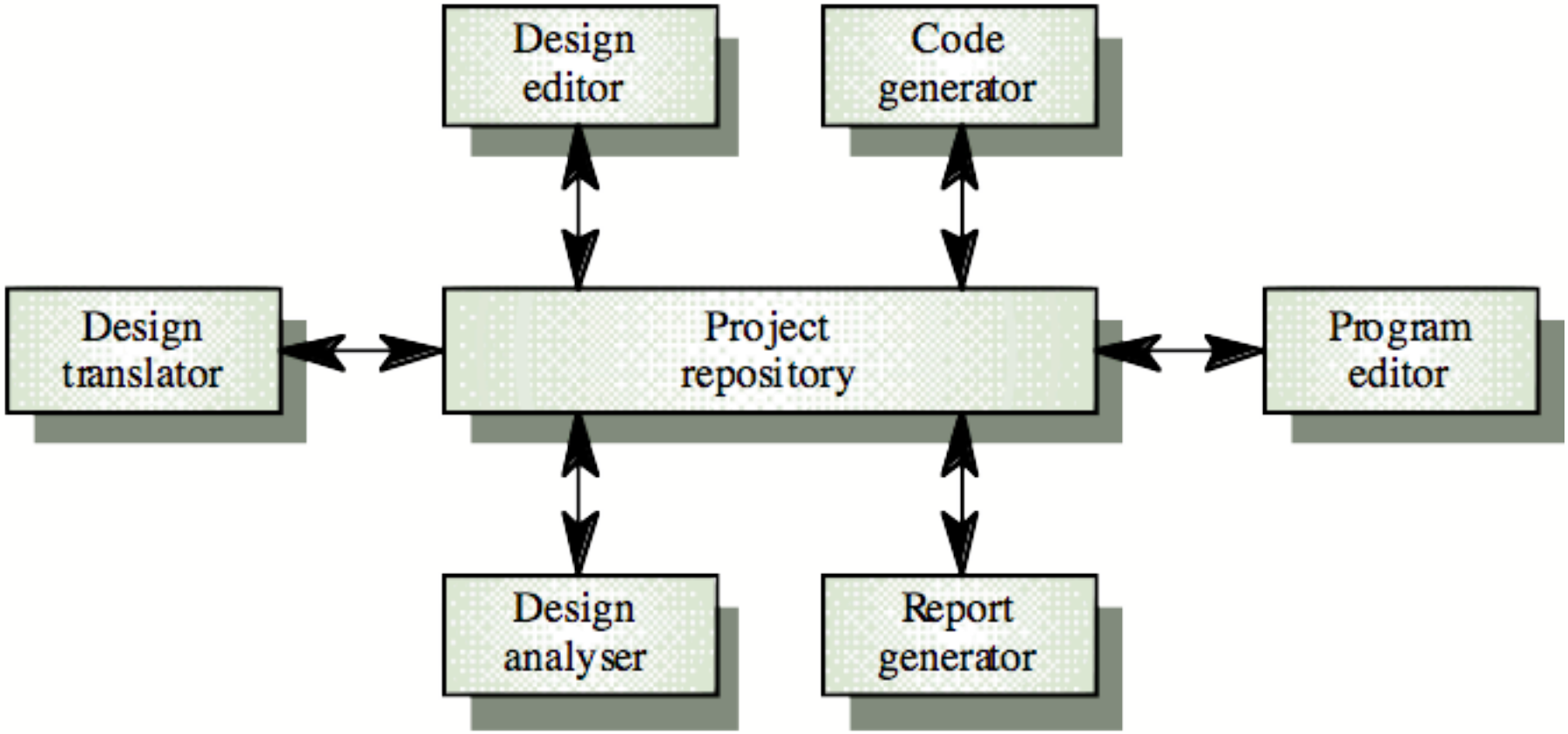
Advantages

- *Efficient way to share* large amounts of data
- Sub-systems need not be concerned with how data is produced, backed up etc.
- Sharing model is published as the *repository schema*

Disadvantages

- Sub-systems must agree on a repository data model
- *Data evolution* is difficult and expensive
- No scope for specific management policies
- Difficult to distribute efficiently

CASE toolset architecture



Event-driven Systems

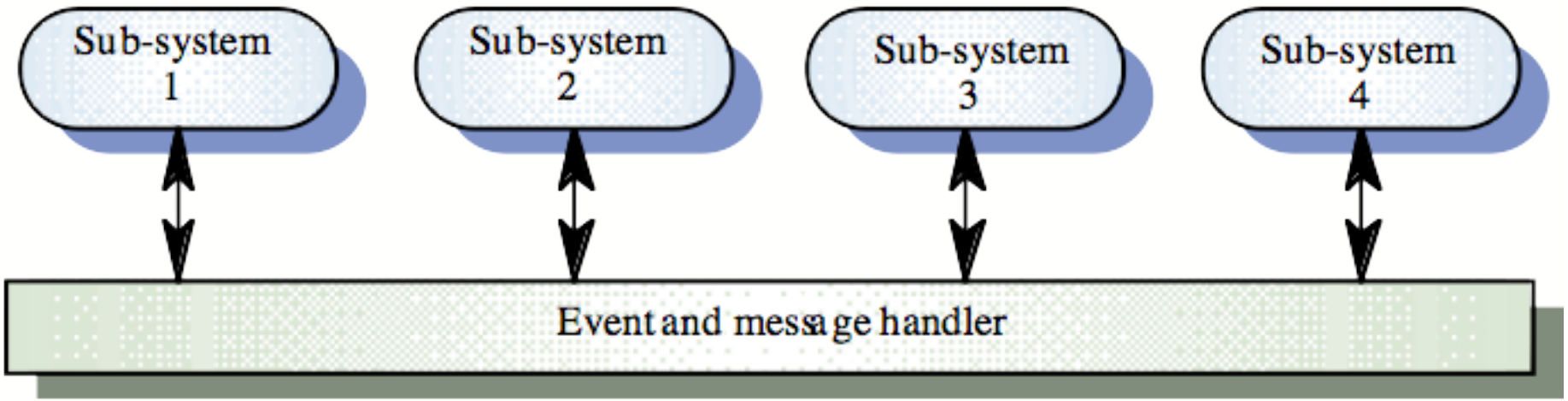
In an event-driven architecture components perform services in *reaction to external events* generated by other components.

- In broadcast models an event is broadcast to all sub-systems. Any sub-system which can handle the event may do so.
- In interrupt-driven models real-time interrupts are detected by an interrupt handler and passed to some other component for processing.

Broadcast model

- Effective in *integrating sub-systems* on different computers in a network
- Can be implemented using a *publisher-subscriber* pattern:
  - Sub-systems register an interest in specific events
  - When these occur, control is transferred to the subscribed sub-systems
- *Control policy is not embedded* in the event and message handler. Sub-systems decide on events of interest to them
- However, sub-systems don't know if or when an event will be handled

Selective Broadcasting



Dataflow Models

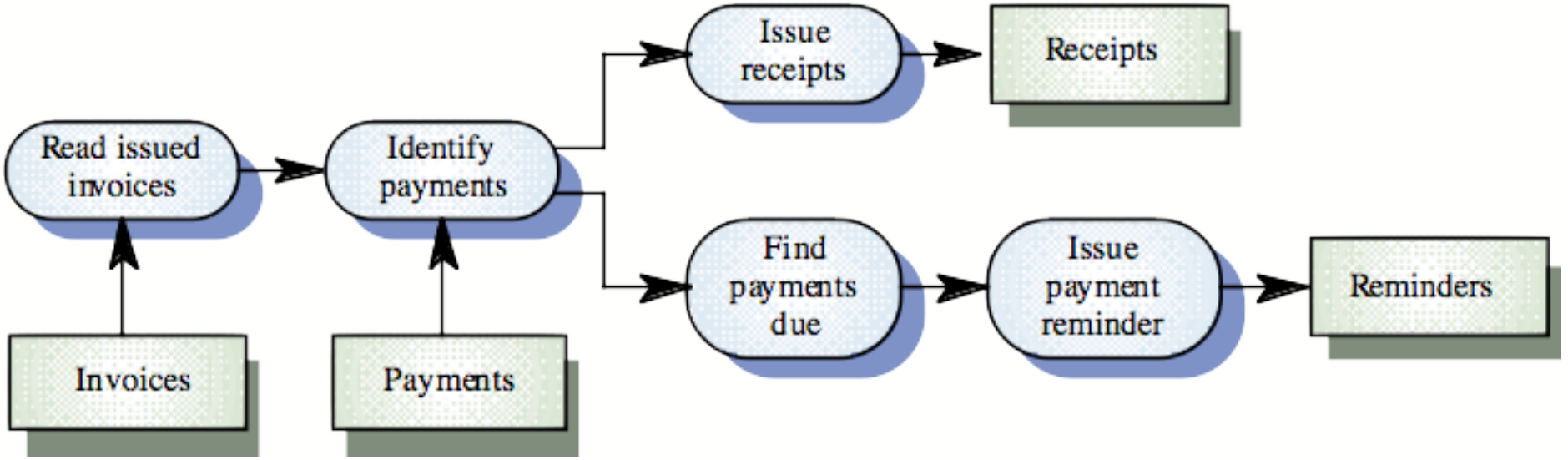
In a dataflow architecture each component performs *functional transformations* on its inputs to produce outputs.

- Highly effective for *reducing latency* in parallel or distributed systems
  - — No call/reply overhead
  - — But, fast processes must wait for slower ones
- Not really suitable for *interactive systems*
  - — Dataflows should be free of cycles

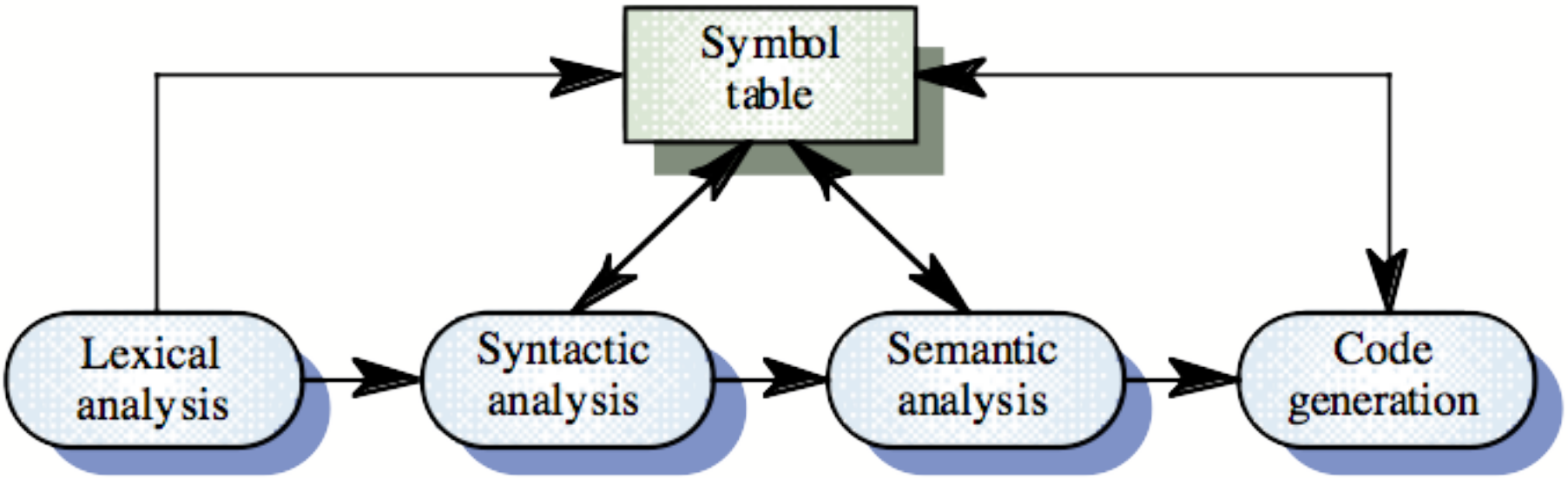
Pipes and Filters

Domain	*Data source*	*Filter*	*Data sink*
Unix	`tar cf - .`	`gzip -9`	`rsh picasso dd`
CGI	HTML Form	CGI Script	generated HTML page

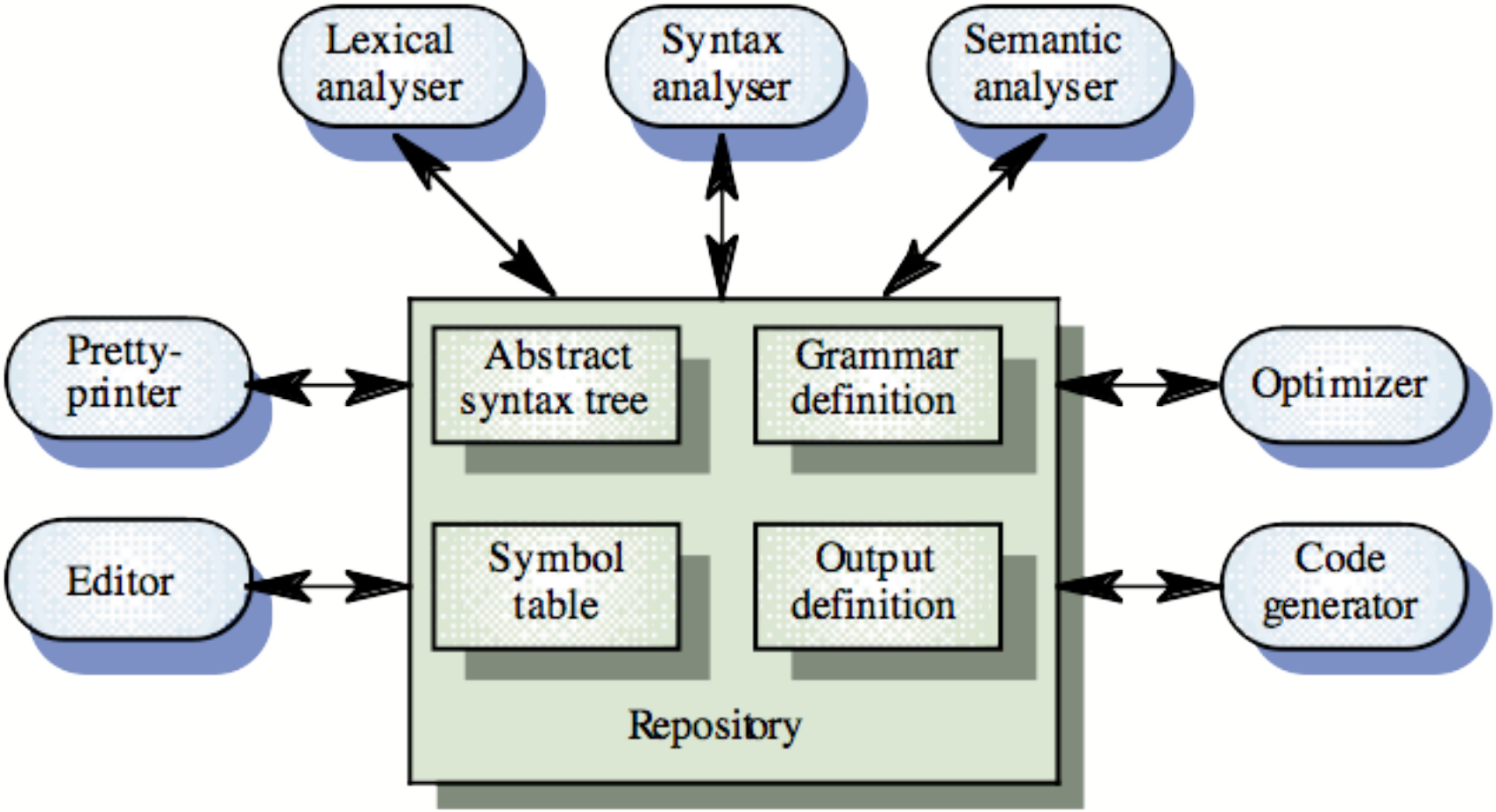
Invoice Processing System



Compilers as Dataflow Architectures



Compilers as Blackboard Architectures



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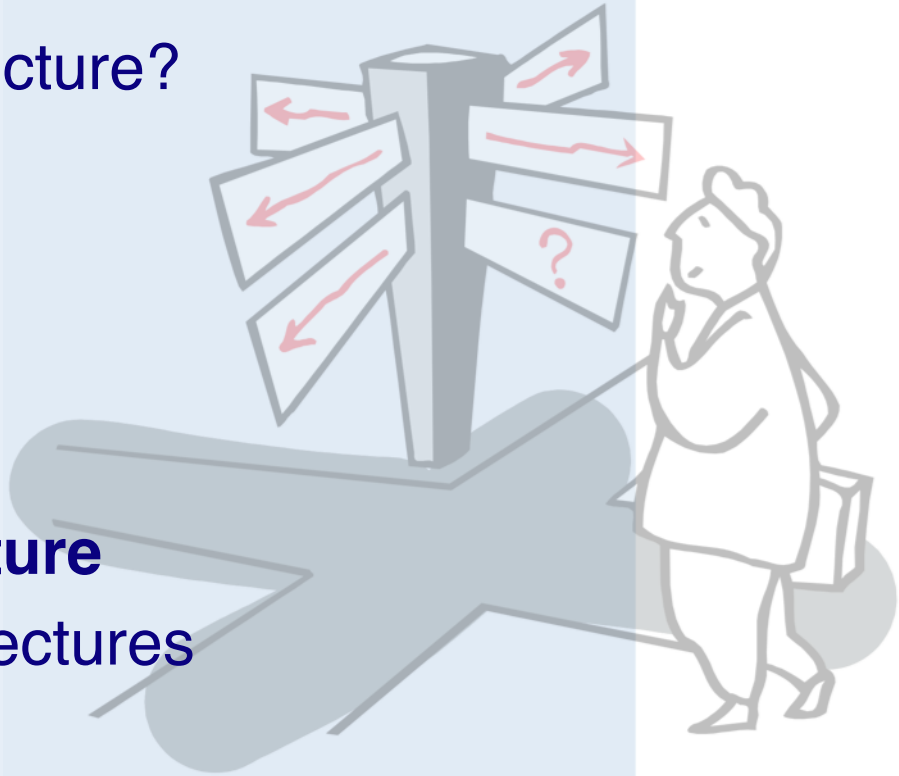
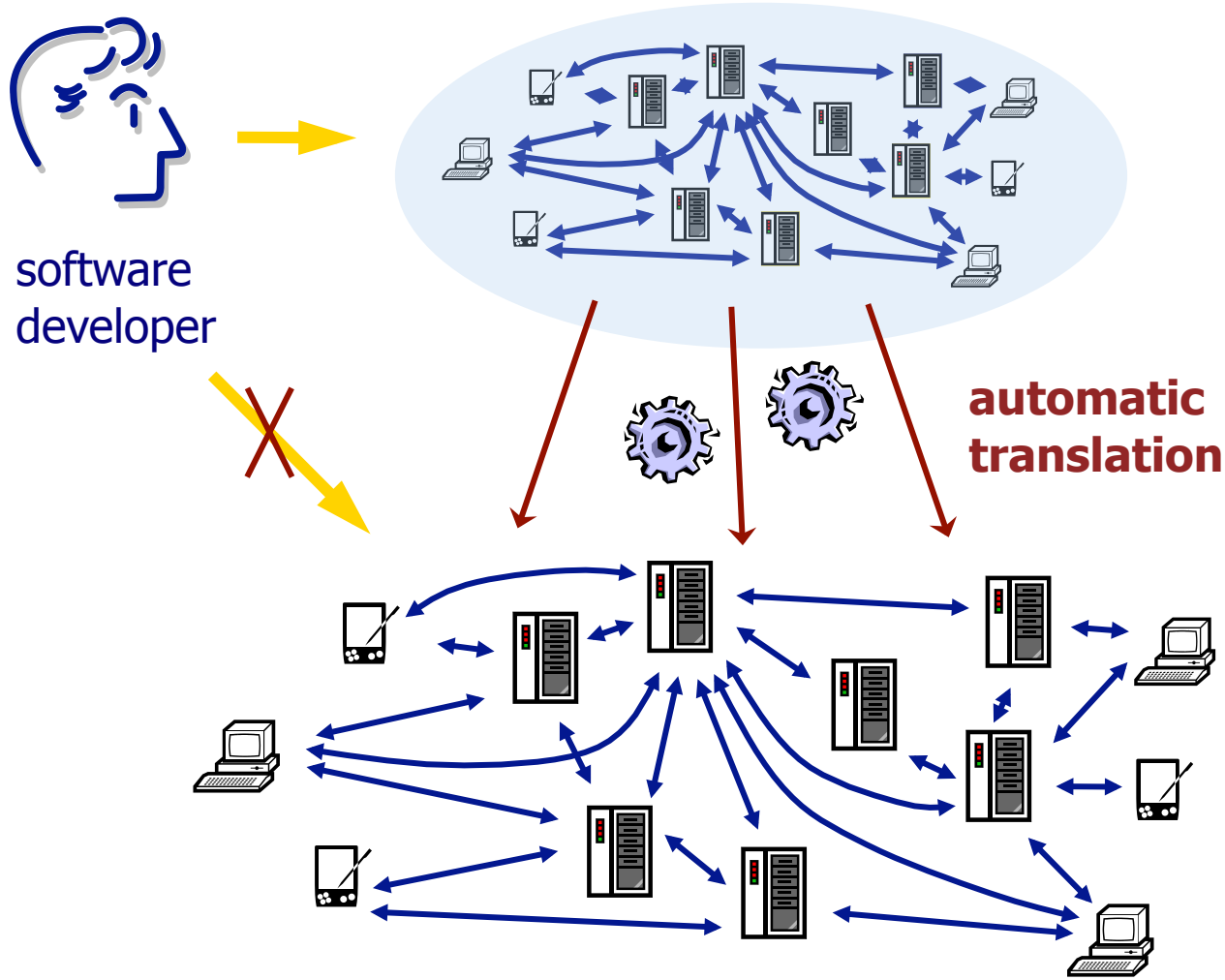
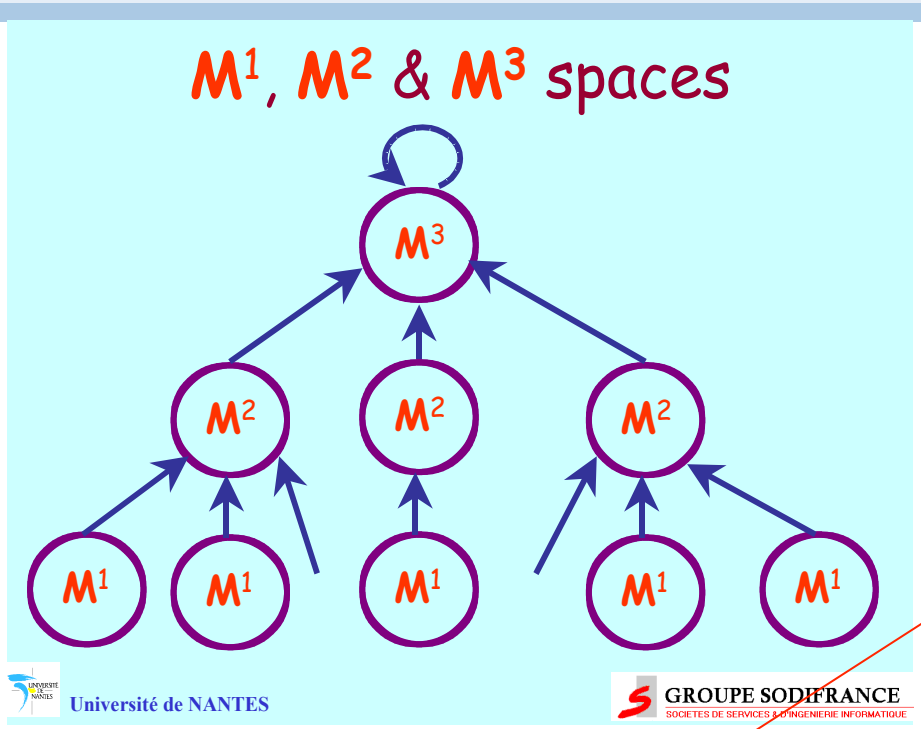


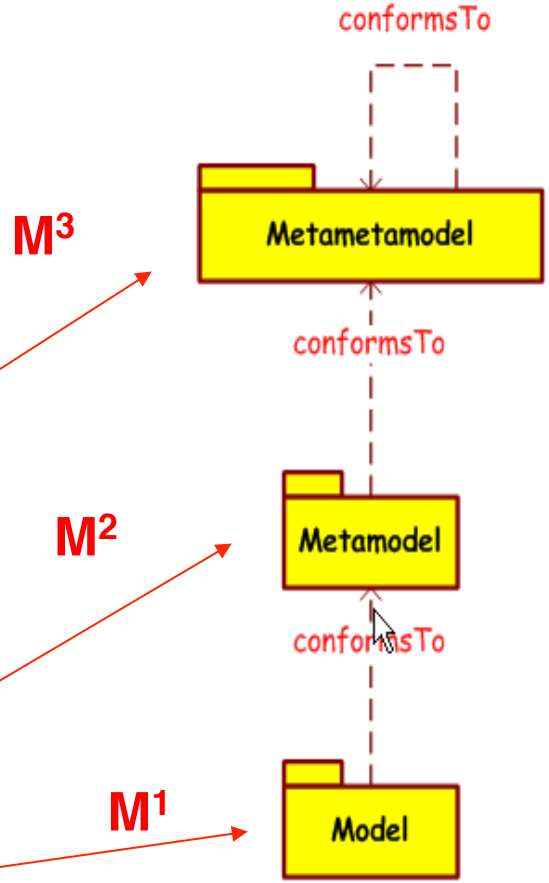
The Vision of MDA



C. Atkinson, U Mannheim

MDA in a nutshell

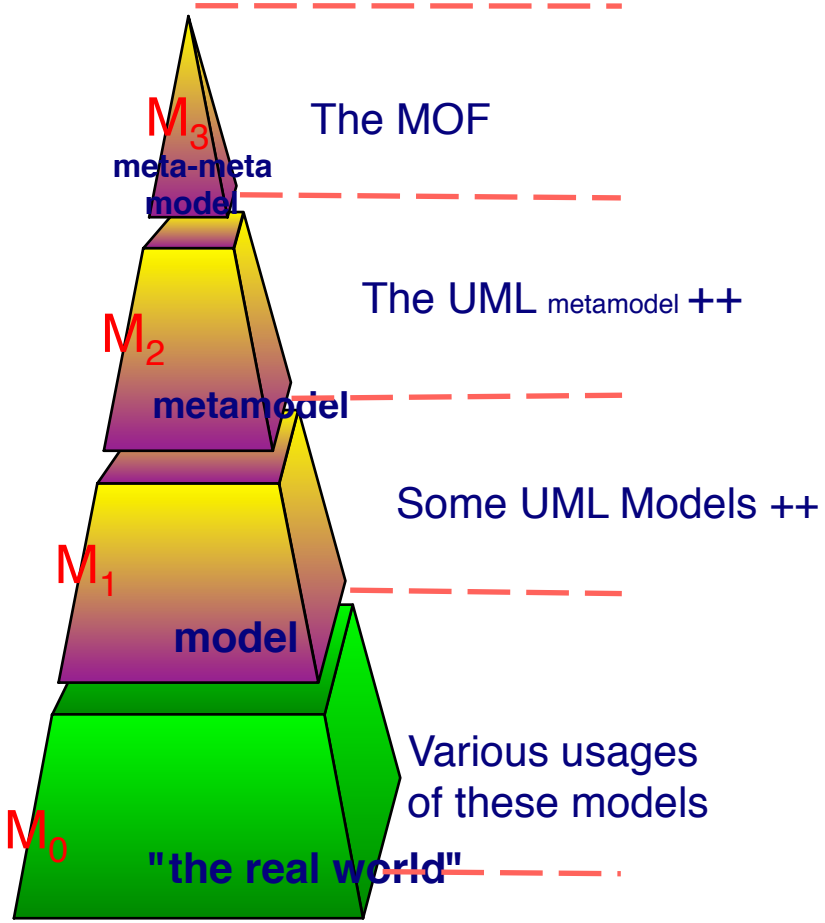


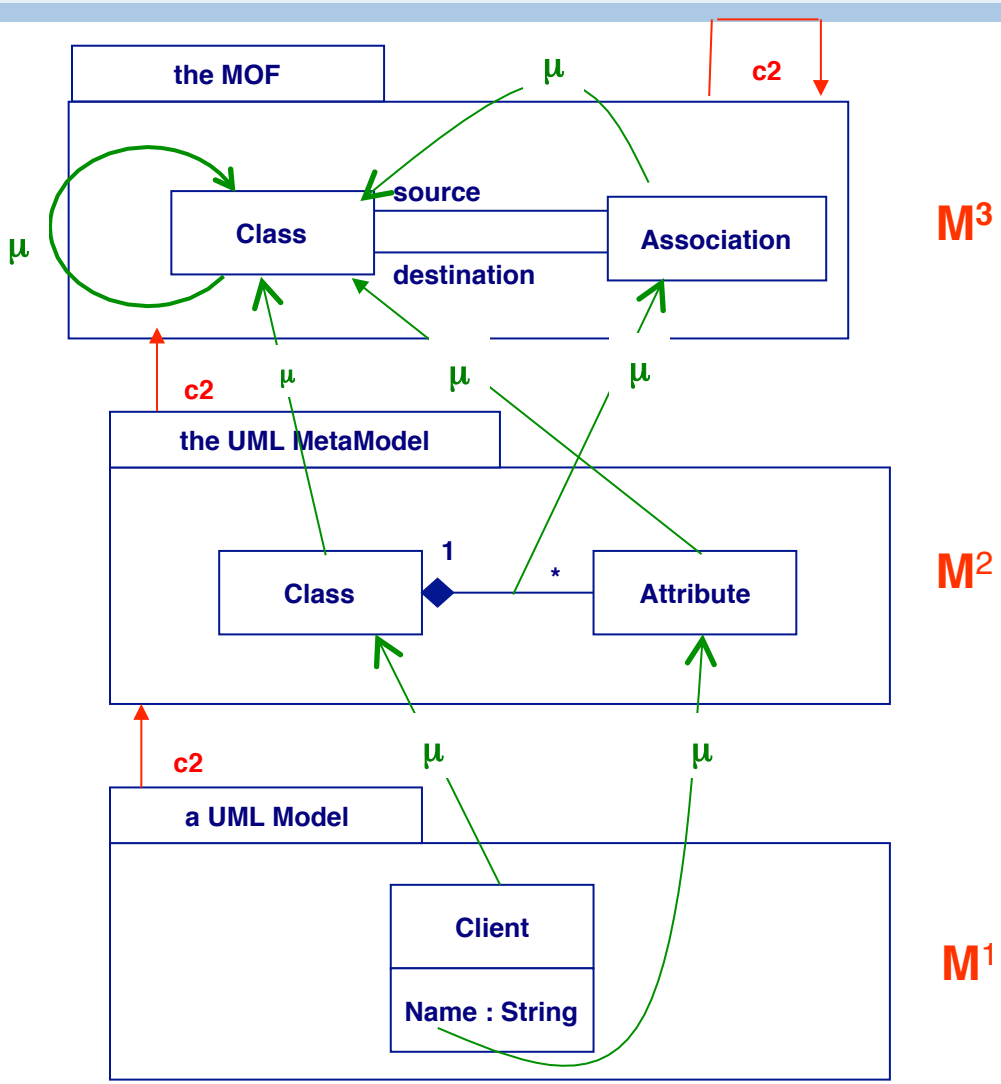


- One unique Metametamodel (the MOF)
- An important library of compatible Metamodels, each defining a DSL
- Each of the models is defined in the language of its unique metamodel

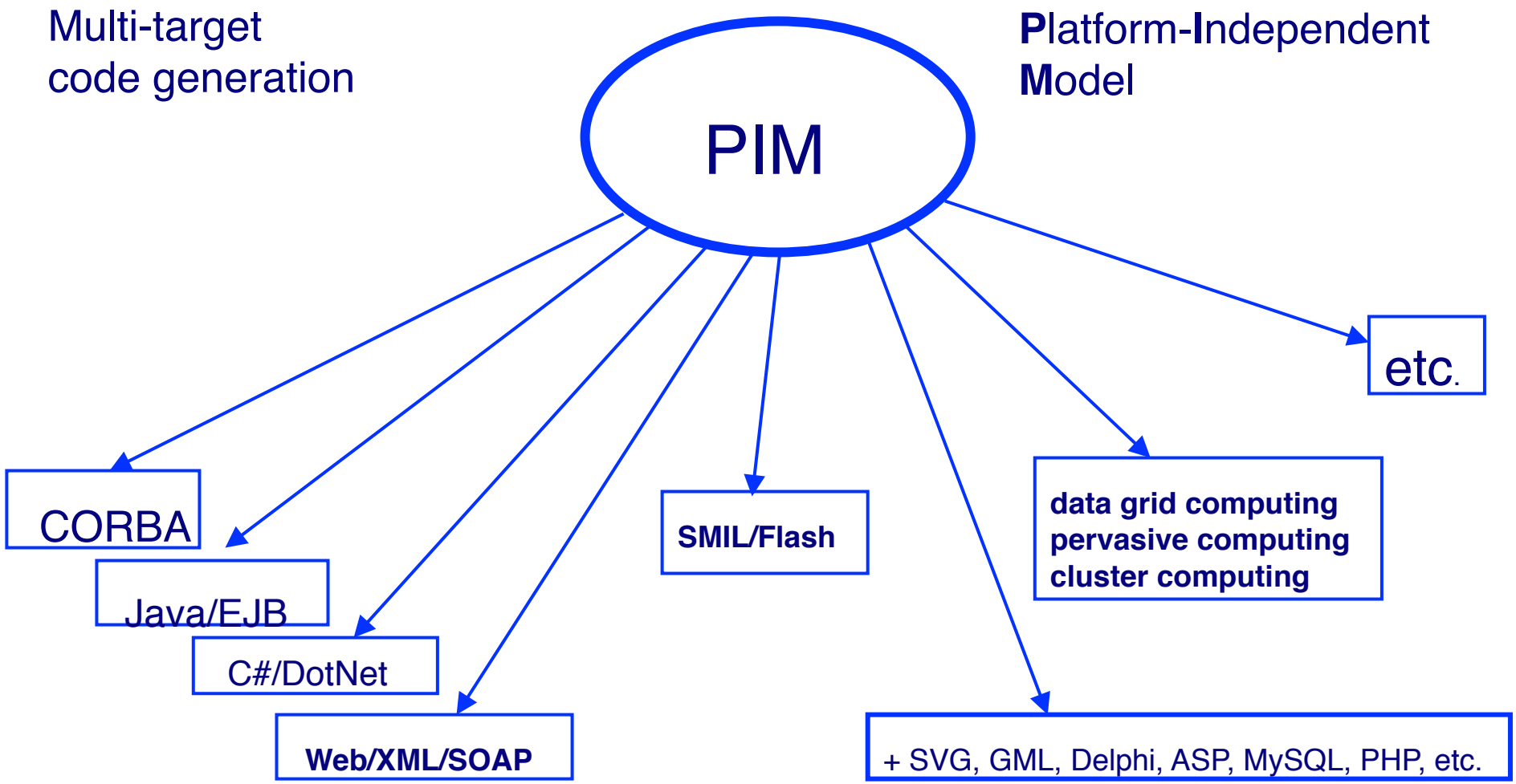
J. Bézivin, ATLAS group, U Nantes

The OMG/MDA Stack





Write Once, Run Anywhere
Model Once, Generate Anywhere



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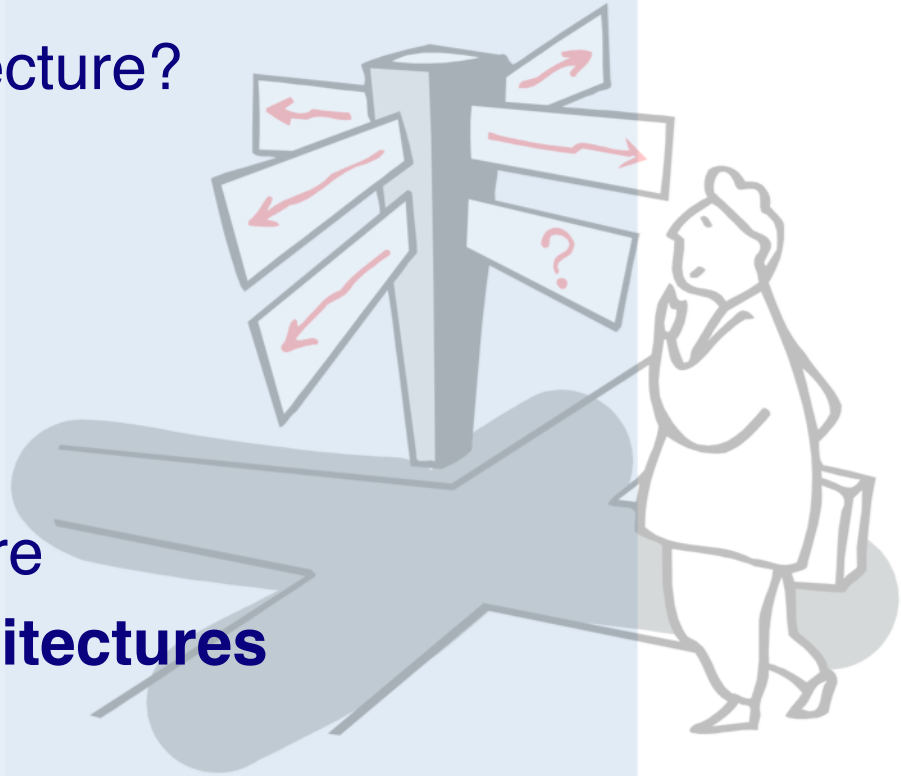

UML support: Package Diagram

Decompose system into *packages* (containing any other UML element, incl. packages)

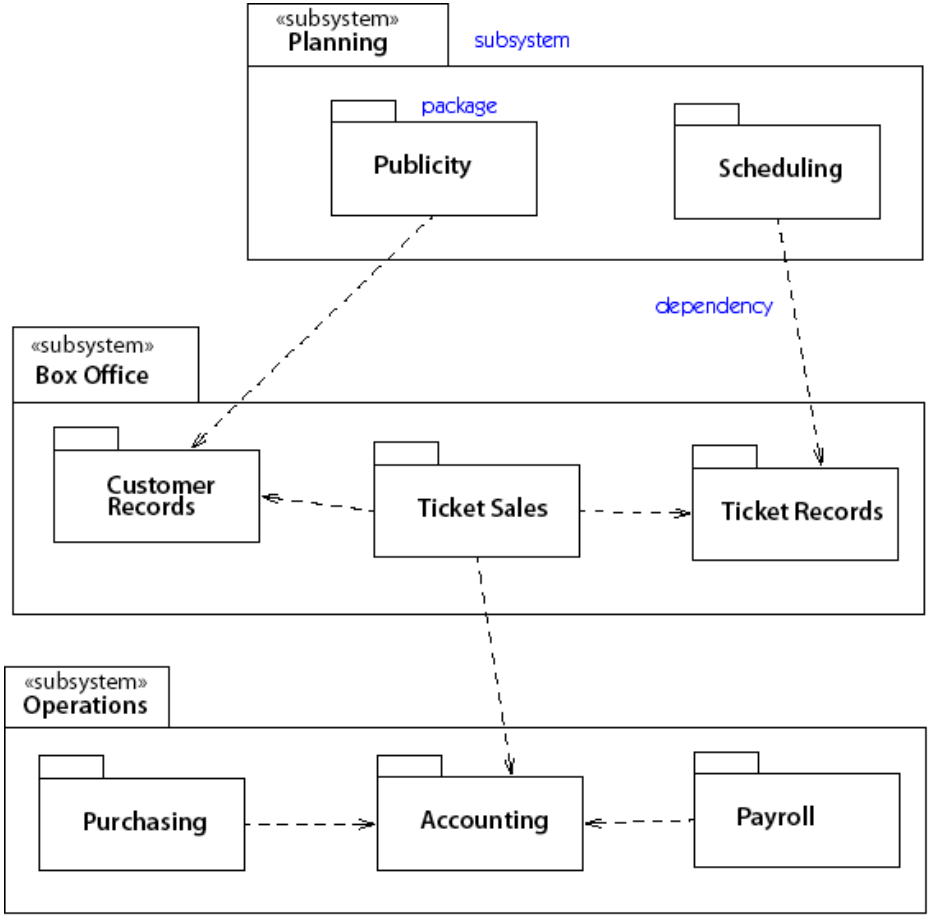

Figure 3-10. *Packages*

UML support: Deployment Diagram

Physical layout of run-time components on hardware nodes.

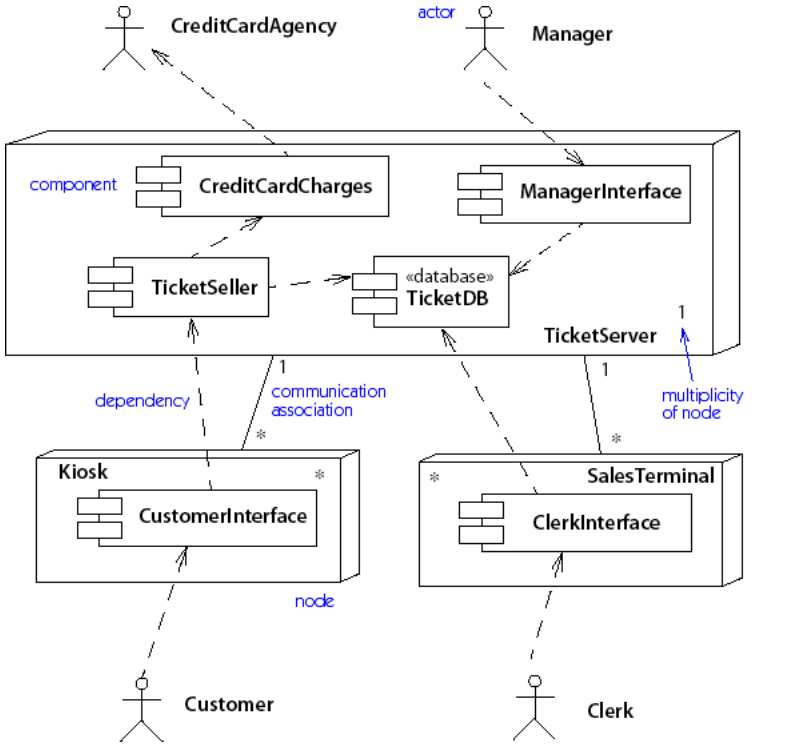

Figure 3-8. *Deployment diagram (descriptor level)*

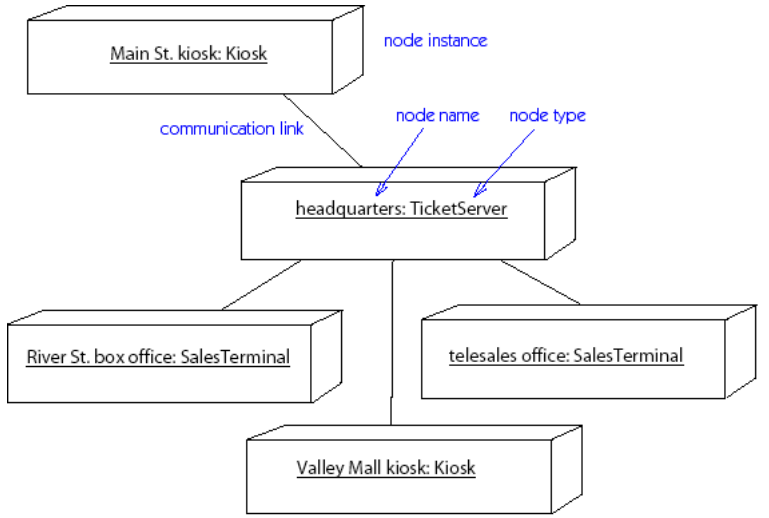

Figure 3-9. *Deployment diagram (instance level)*

What you should know!

- How does software architecture constrain a system?
- How does choosing an architecture simplify design?
- What are coupling and cohesion?
- What is an architectural style?
- Why shouldn’t elements in a software layer “see” the layer above?
- What kinds of applications are suited to event-driven architectures?

Can you answer the following questions?

- What is meant by a “fat client” or a “thin client” in a 4-tier architecture?
- What kind of architectural styles are supported by the Java AWT? by RMI?
- How do callbacks reduce coupling between software layers?
- How would you implement a dataflow architecture in Java?
- Is it easier to understand a dataflow architecture or an event-driven one?
- What are the coupling and cohesion characteristics of each architectural style?

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