iPOJO: A Flexible Service-Oriented Component Model for Dynamic Systems

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Two Parallel Evolutions

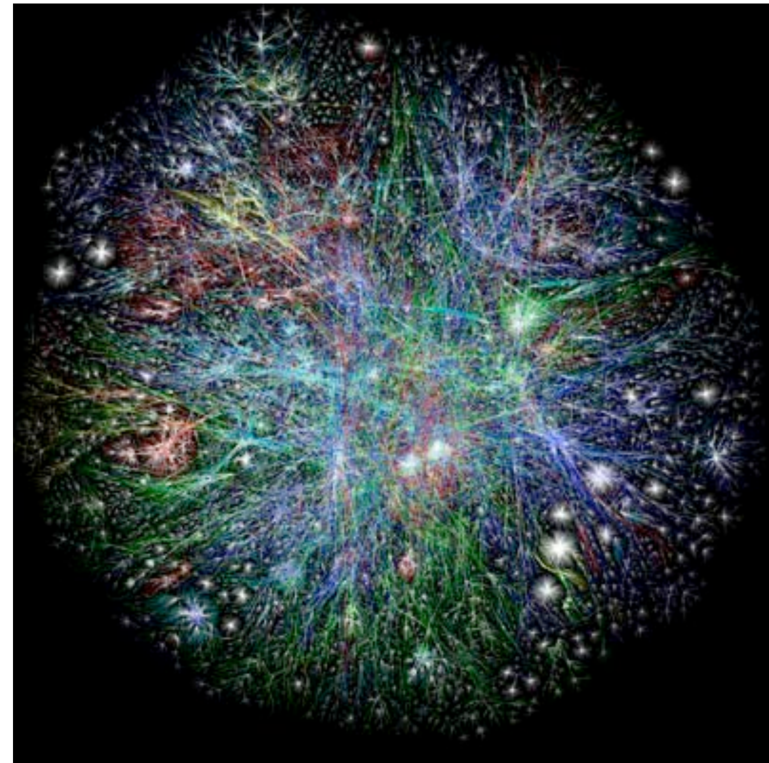
- Internet & The Web
  - From static web to dynamic content
  - Blur boundaries between desktop and Internet
  - Towards Web 3.0

- Ubiquitous computing
  - Communicative & pervasive objects
  - Exponential growth
  - Seamless integration in the daily life
  - Towards ambient intelligence

The "Crunch"

- Convergence between Internet and Ubiquitous Computing
  - Smart objects bring Internet closer to users

- Paves the road to new types of applications
  - Machine-to-machine
  - Home applications



THE "CRUNCH"

- A challenging convergence!
  - Requires facilities to design, develop, execute and manage.

- Emergence of *new* stringent requirements
  - Scalability
  - Security
  - Autonomy
  - Heterogeneity
  - Evolution

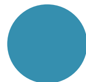
The "Crunch"

- A challenging convergence!
  - Requires facilities to design, develop, execute and manage.

- Emergence of *new* stringent requirements
  - Scalability
  - Security
  - Autonomy
  - Heterogeneity
  - Evolution

Outline

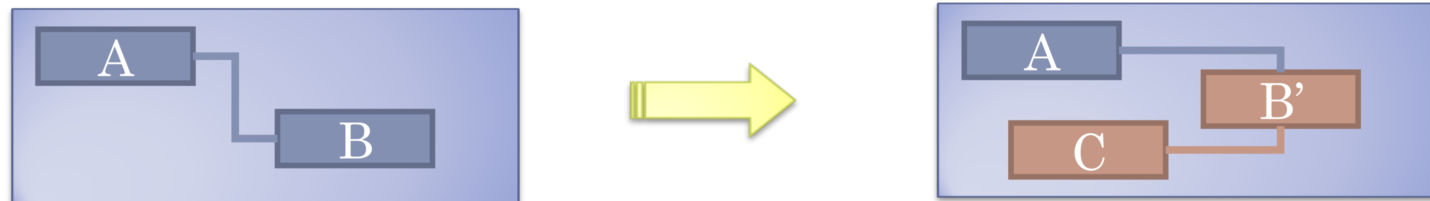
- Being Dynamic, Why, What and How ?
- Service-Oriented Computing & Dynamism
- Problematic & Objectives
- iPOJO: Principles & Concepts
- Dynamism in Atomic & Composite Components
- Implementation & Validation
- Conclusion & Perspectives



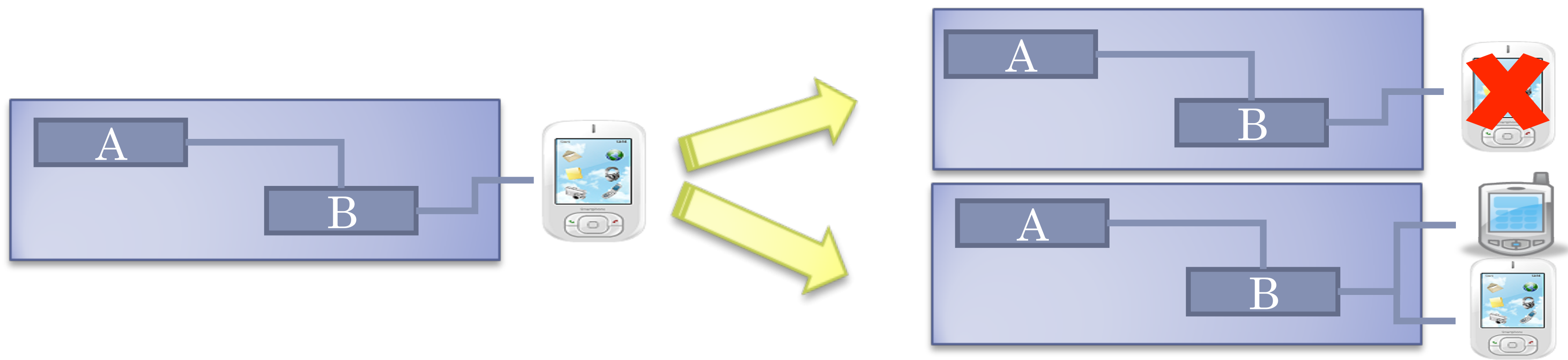
Being Dynamic

Why, What and How ?

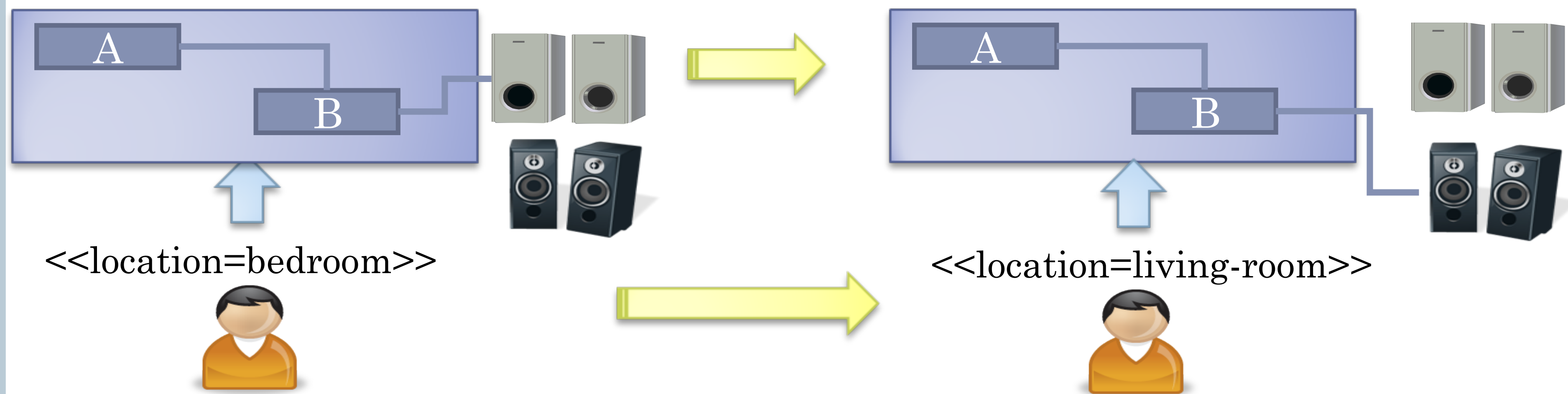
What Does "Dynamic" Mean?
Internal Evolution



WHAT DOES "DYNAMIC" MEAN?
ENVIRONMENTAL CHANGES



What Does "Dynamic" Mean?
Contextual Changes



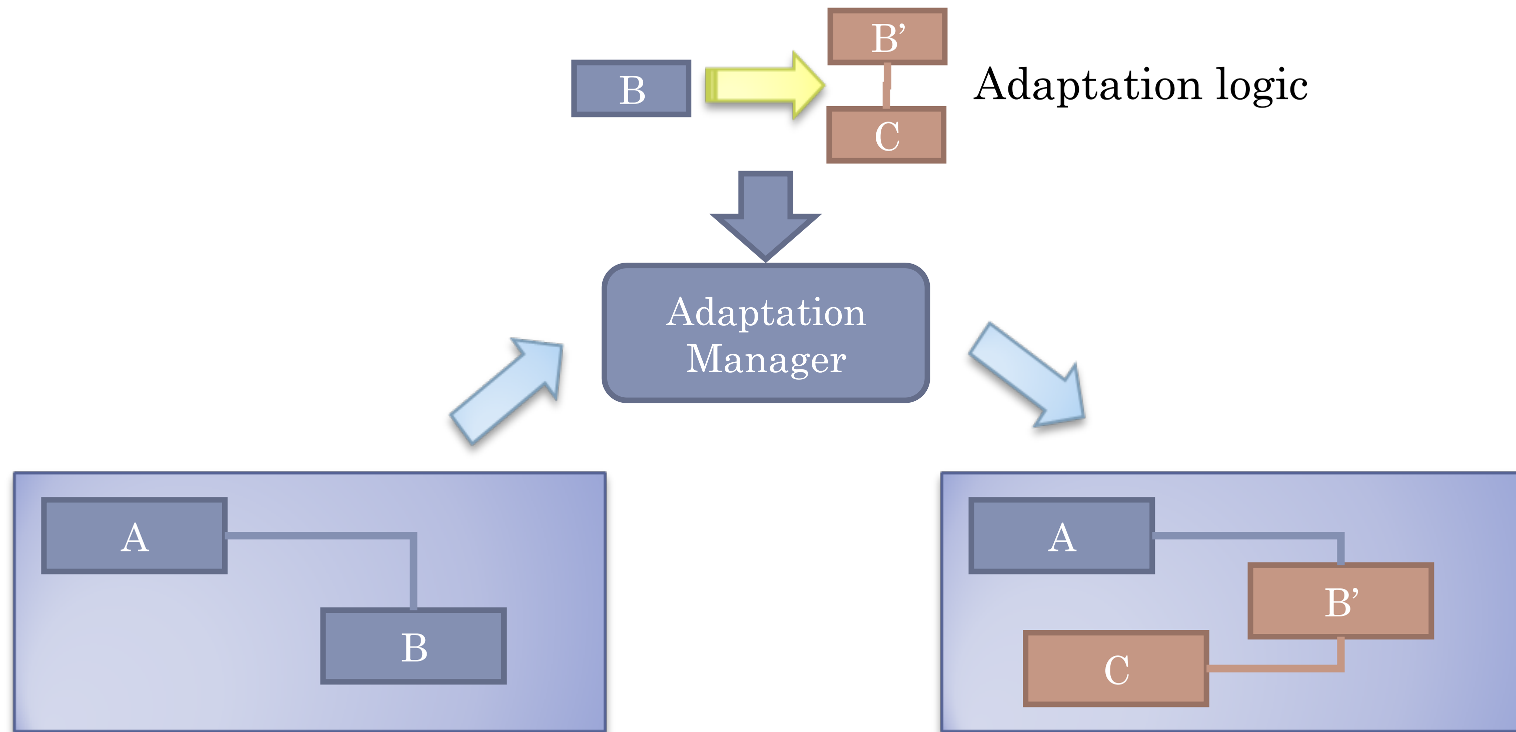
WHAT IS A "DYNAMIC APPLICATION" ?

- Dealing with dynamism impacts the architecture
  - Adding, removing, updating components
  - Modifying connectors

A dynamic application is an adaptable application supporting the modification of its architecture during its execution

- Flexible, efficient …. complex to design, develop, execute and manage!

How Is An Application "Adapted"?



- Guarantying application consistency is complex
  - Notions of quiescence / tranquility states

EXISTING APPROACHES

- *Ad-hoc* approaches
  - Context-aware applications, product-lines, autonomic,
  - Hard to generalize
- Component models supporting dynamic reconfiguration
  - SOFA/DCUP, OpenRec, …
  - Focused on a given type of dynamism, lack of flexibility
- Extended architecture description languages
  - Darwin, Dynamic Wright, C2ADEL, …
  - Big gap between such languages and execution frameworks

SYNTHESIS

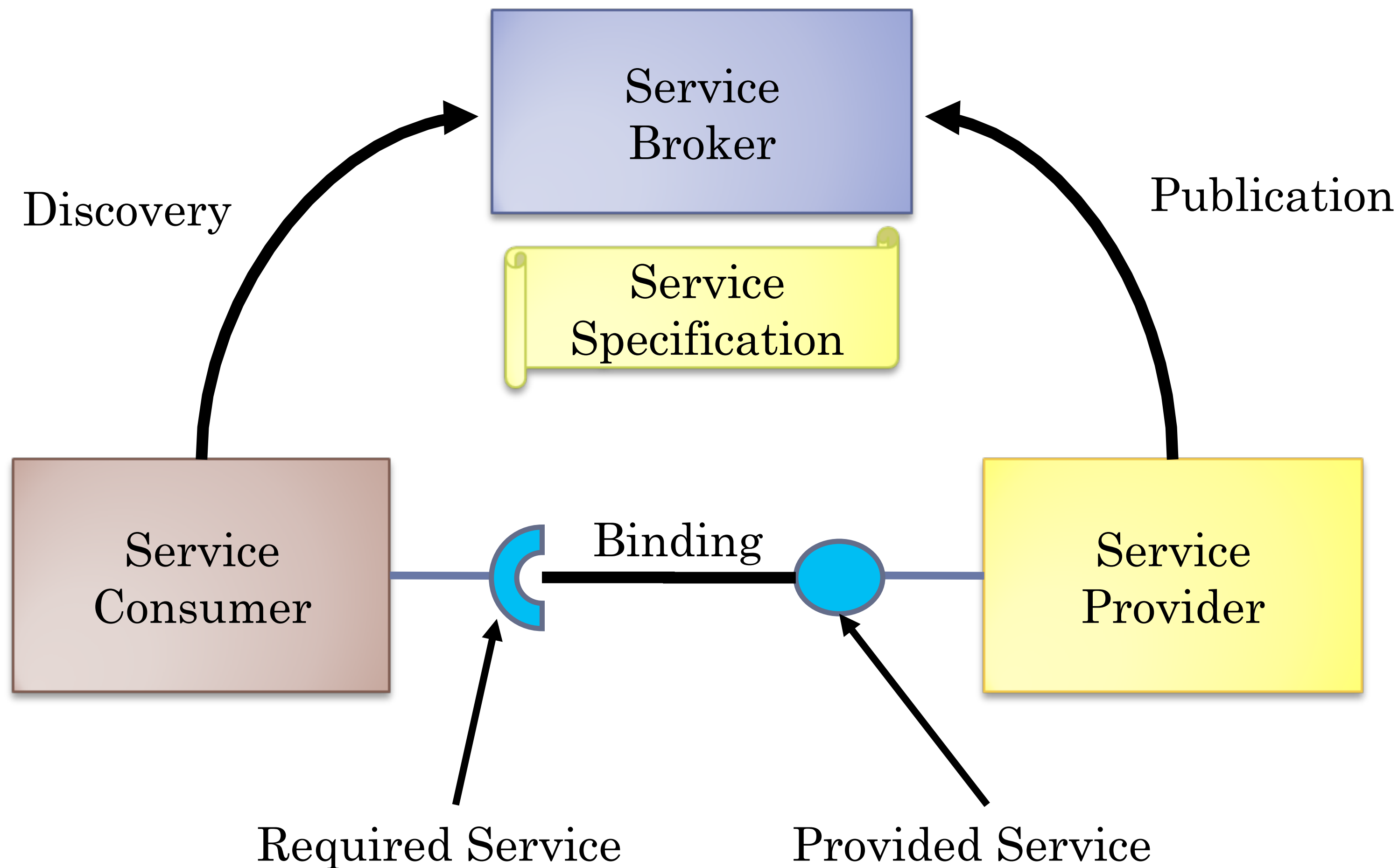
- Dynamism is today needed but extremely complex to manage

- Existing solutions are limited
  - Require a lot of design and development effort
    - State management, synchronization, …
  - Do not always support the different types of dynamism
    - Constrained to specific domains
    - *Ad-hoc* mechanisms

SERVICE-ORIENTED COMPUTING & DYNAMISM

Towards Dynamic Extended Service-Oriented Architecture

Service-Oriented Computing (SOC)
"Publish-Find-Bind"

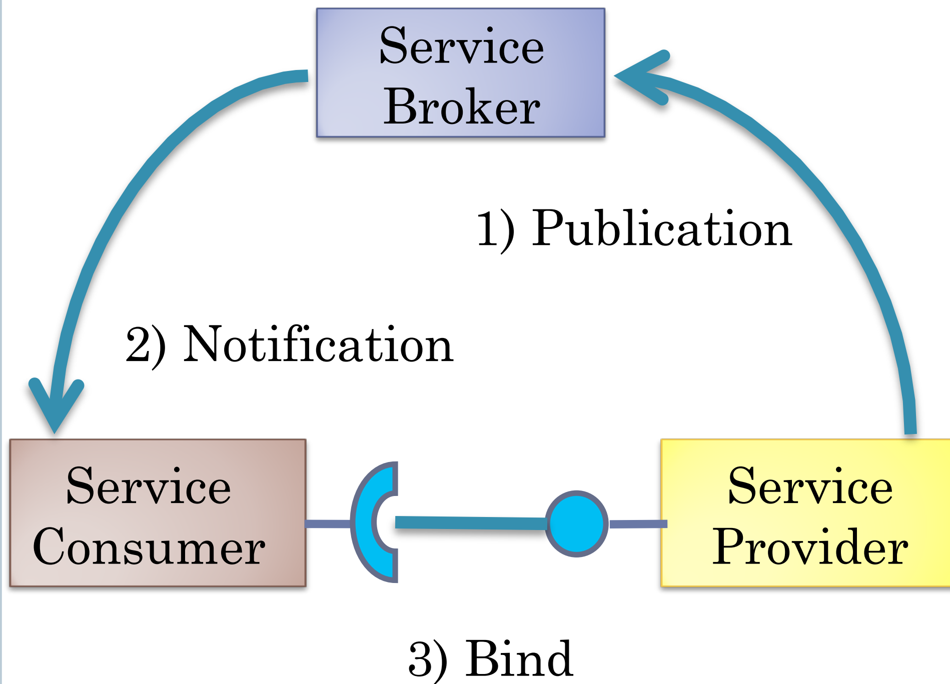


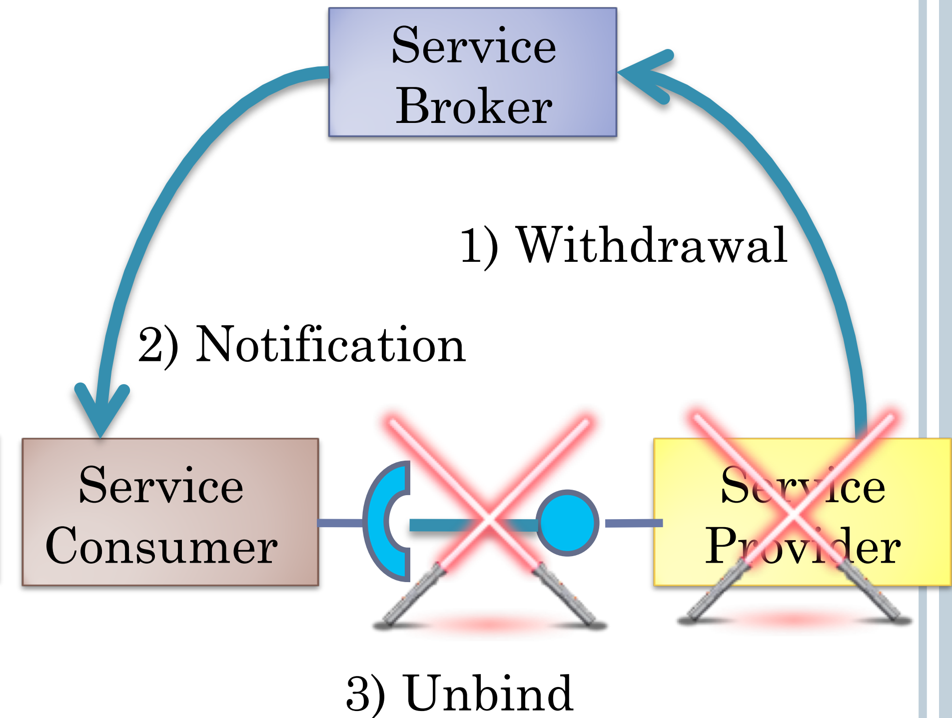
MAIN CHARACTERISTICS

- Loose-coupling : only the specification is shared
- Late-binding: on-demand binding
- Substitutability: a provider can be replaced

SOC interactions can happen at runtime: Consumers can adapt themselves to service dynamism

Dynamic SOC



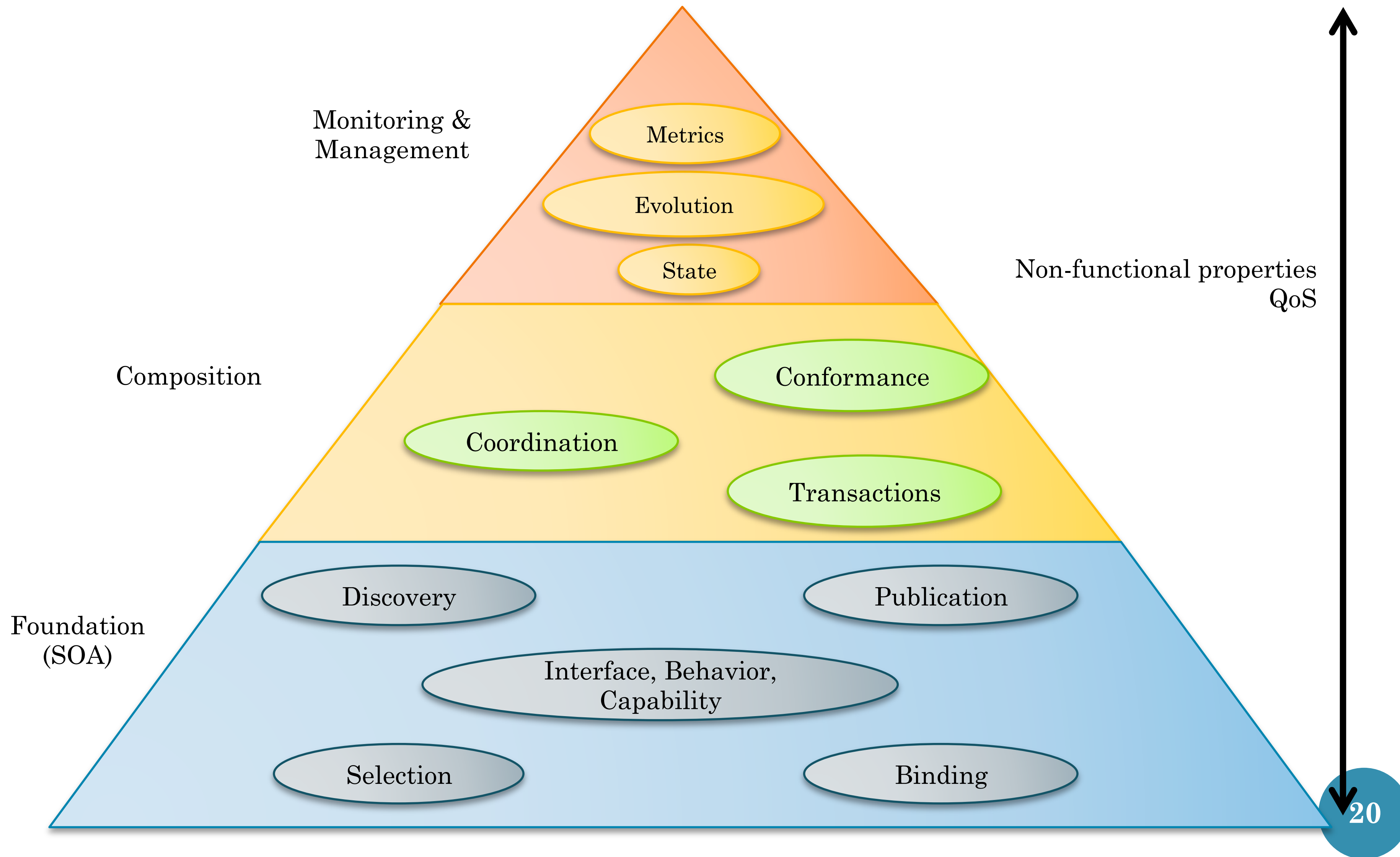


SERVICE-ORIENTED ARCHITECTURE (SOA)

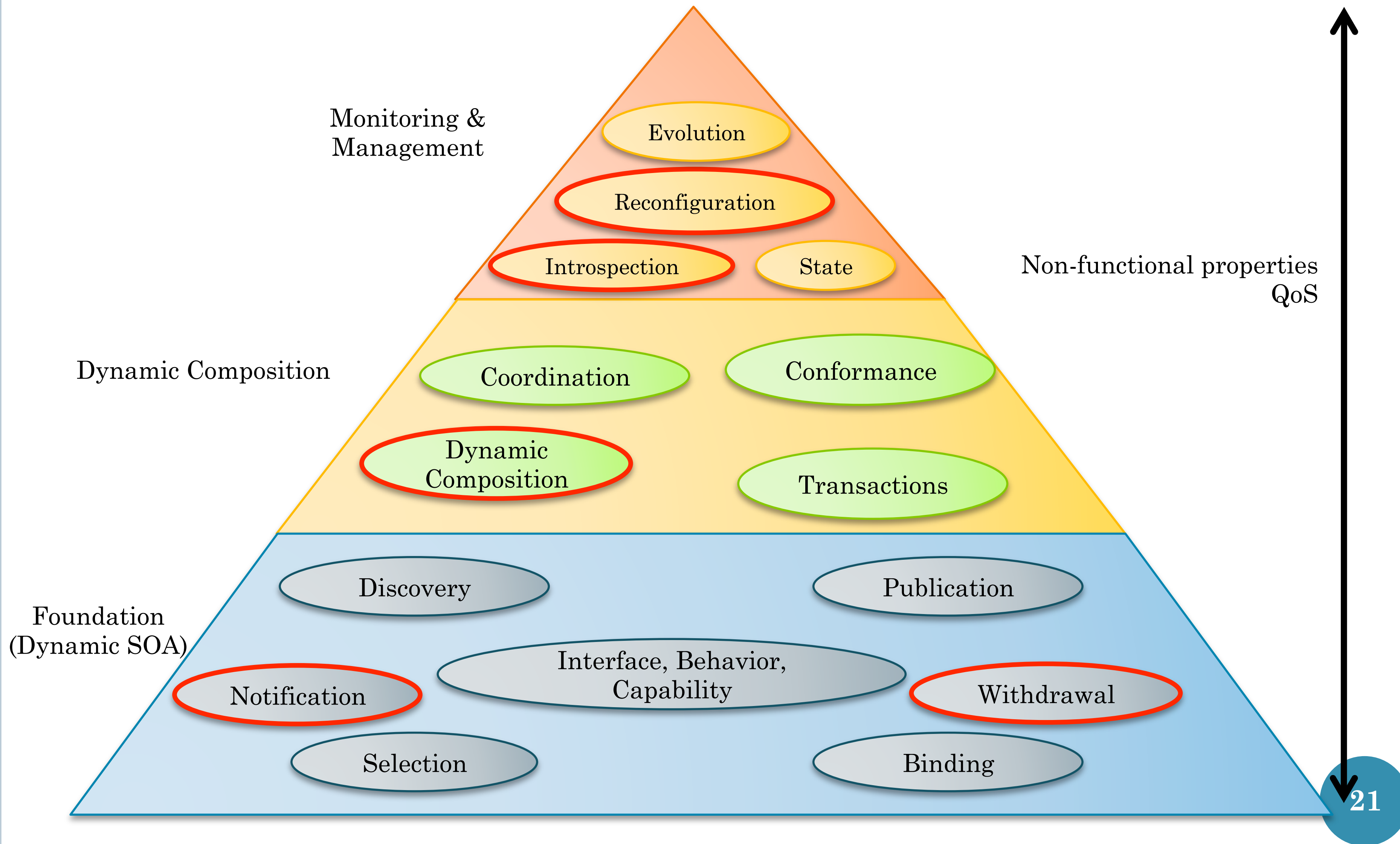
- SOA, a technical environment made of:
  - A service specification format
  - A publication/query mechanism
  - An interaction protocol

- Examples
  - WS: <WSDL, UDDi, SOAP>
  - Corba: <IDL, Corba Trading Service, IIOP> **Dyn.**
  - Jini: <Interface Java, Discovery Service, RMI> **Dyn.**
  - OSGi™: <Interface Java, Service Registry, Direct> **Dyn.**

Extended SOA (from Papazoglou)



Dynamic Extended SOA (Proposed)



SUMMARY: SOC, SOA, EXTENDED SOA AND FRIENDS…

- SOC
  - Paradigm based on services promoting loose-coupling
- SOA
  - Set of technologies allowing the development and execution of applications following SOC principles
- Dynamic SOC
  - Paradigm based on the SOC but adding primitives to support dynamism
- Dynamic SOA
  - Set of technologies allowing the development and execution of dynamic applications following dynamic SOC principles
- Extended SOA
  - Set of technologies allowing the development, composition, management and execution of applications following SOC principles.
  - Is based on a SOA
- Dynamic Extended SOA
  - Set of technologies allowing the development, composition, management and execution of applications following dynamic SOC principles.
  - Is based on a dynamic SOA

SERVICE-ORIENTED COMPONENT MODELS (SOCM)

- SOCM infuses SOC dynamic principles inside component models

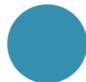
- Principles (Cervantes, Hall):
  - A service is a specified functionality
  - A component instance provides and requires services
  - Bindings between instances follow the SOC dynamic interaction pattern
  - Compositions are described in terms of specifications
  - Service specifications form the basis for substitution

Are SOCM Dynamic Extended SOA?

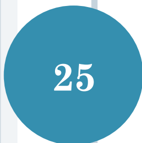
- Yes, SOCM:
  - are based on a dynamic SOA
  - provide composition mechanisms
  - provide monitoring and administration mechanisms

- But … No! Existing SOCM don't provide all capabilities
  - Focus on the development model simplification
    - SCR, Spring-DM
  - Compositions are generally not supported (or are static)
    - Apache Tuscany (SCA), Spring-DM
  - Administration and monitoring funct. are very limited

But it is a promising path



Problematic and Objectives

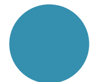


DYNAMIC APPLICATIONS
CURRENT STATE

Approaches	Pros	Cons
Component Models	• Structural composition • Simplify the dev. model	• Lack of flexibility • Difficulties to manage contextual and env. dynamism
Dynamic Service Oriented Architecture	• Loose-coupling • Late binding • Substitutability	• No architectural view • No admin. features • Development model difficult to control
Service-Oriented Component Models *(Dynamic Extended SOA)*	• Structural composition • Simplify the dev. model • Handle dynamism	• Composition rarely provided or static • Has generally an impact on the application code

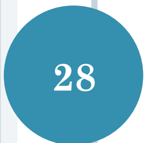
Goal: A Service-Oriented Component Model

- Providing a component model supporting dynamism and an associated execution framework
- Defining a service oriented architecture providing features to manage dynamism and structural compositions
- Proposing an “as simple as possible” development model
- Defining a composition language
- Providing introspection and reconfiguration capabilities
- Providing an extensibility mechanism to adapt the component model, and the runtime



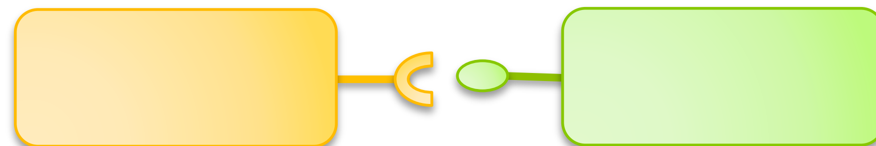
iPOJO

Principles & Concepts



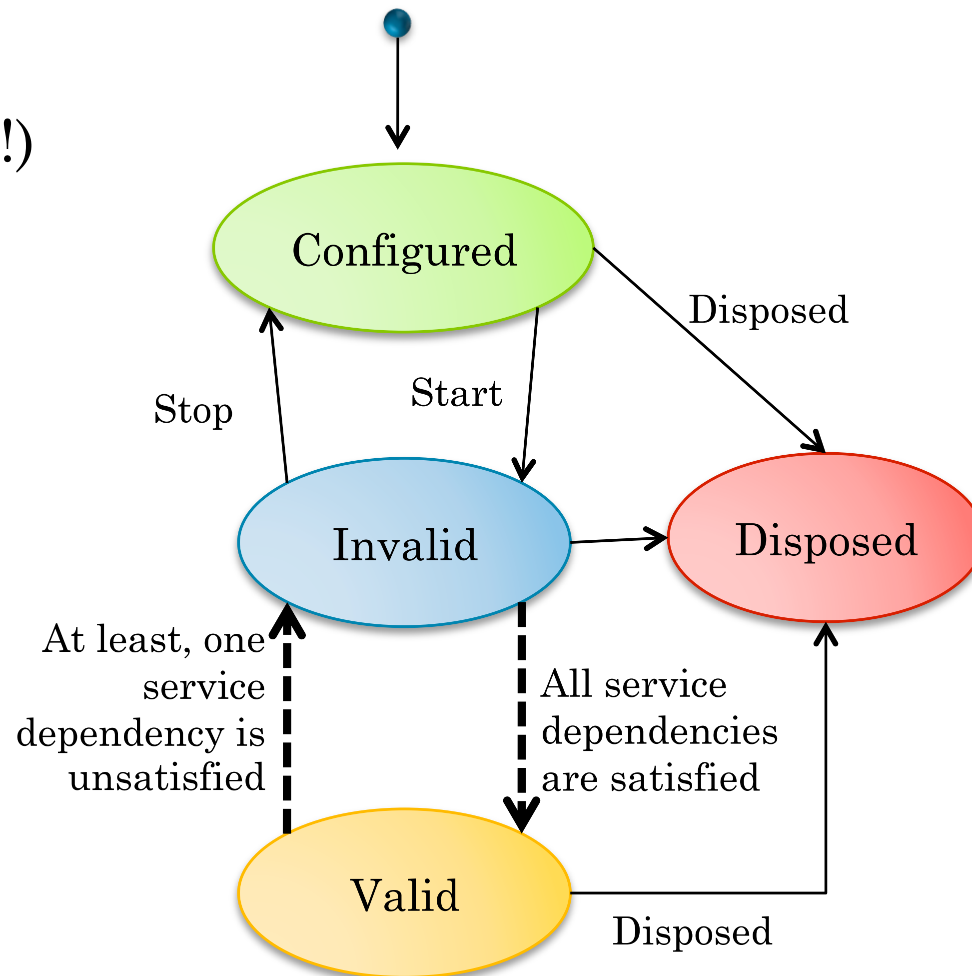
iPOJO, Our Proposal

- A service-oriented component model
  - Supporting structural compositions
    - Hierarchical
  - Built applications are natively dynamic
  - Extensible (implemented with an open container)
- Key concepts
  - Service implementations and instances
  - A service specification model
  - A service dependency model
  - Service context



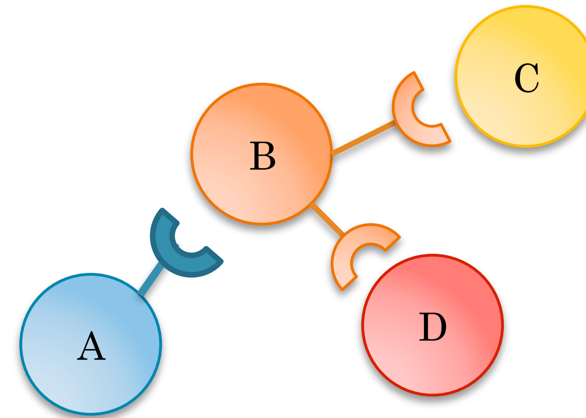
Component Types & Instances

- Component Types
  - Implementations (code!)
  - Describe provided and required services
  - Supports updates
- Instances
  - "*Living*" entities
  - Requires and Provides services
  - *Introspectable*



Service Specification

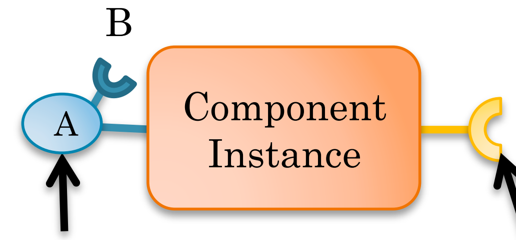
- A service is described with
  - Java interface
  - Properties (open set)
  - State
  - Service dependencies



- Designed to support structural composition
  - Applications are designed using composable services specification

A Rich and Flexible dependency Model

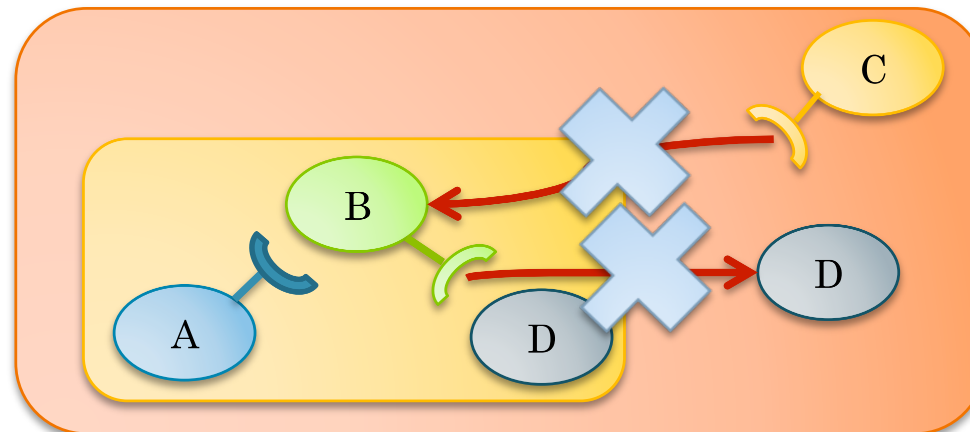
- Two levels of dependencies
  - Service-level
  - Implementation-level



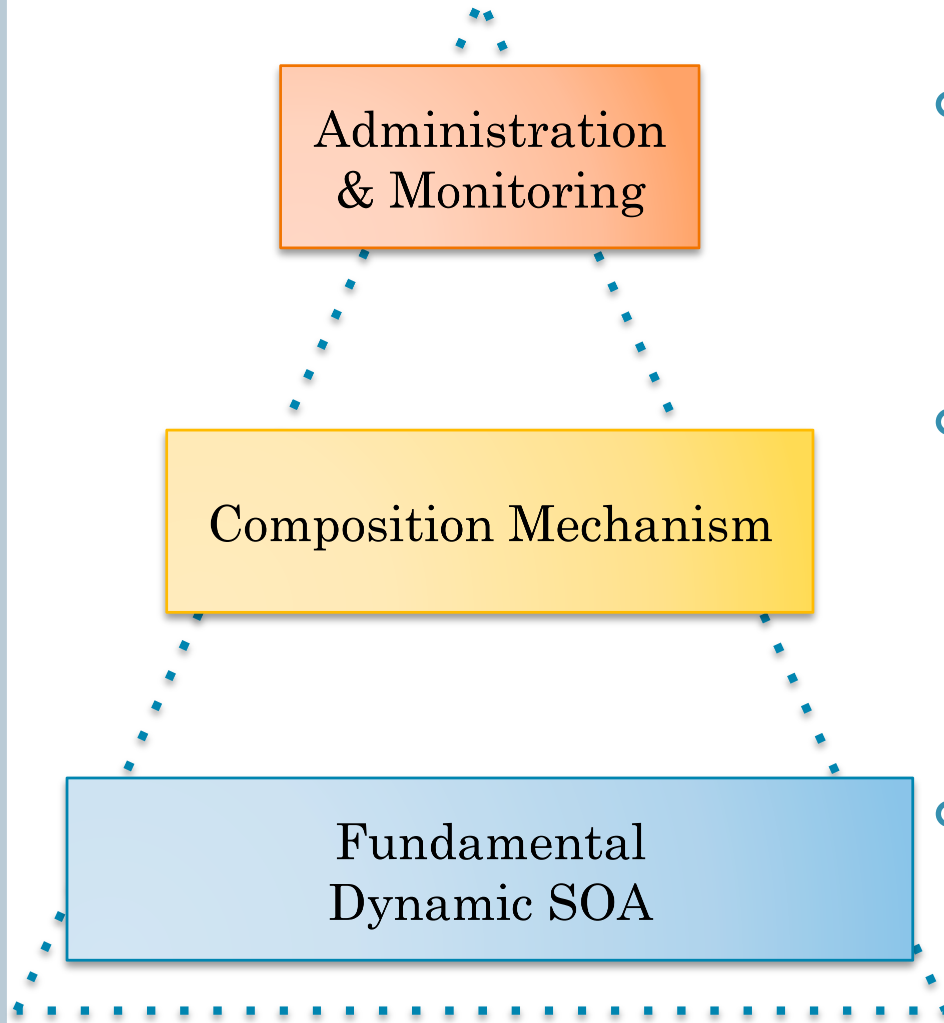
- A dependency targets a service specification
  - scalar or aggregate
  - optional or mandatory
  - can be filtered and/or sorted
  - binding policies
    - Dynamic, Static, Dynamic-Priority
- Properties
  - Reconfigurable, *Introspectable*

Service Context

- Hierarchical structural Service Composition
- Support service isolation
  - Notion of *service contexts*
    - Equivalent to isolated dynamic SOAs
  - Each composition has its own service context
    - Isolates instances created in the composition



iPOJO & Extended Dynamic SOA



- Supports Evolution, Introspection, Reconfiguration
- Provides mechanism to execute dynamic hierarchical structural service composition
  - Service Specification model
  - Dependency Model
- Provides a hierarchical dynamic SOA
  - Service Context
  - Service Implementation/Service Instance

Dynamism Management in Atomic & Composite Components

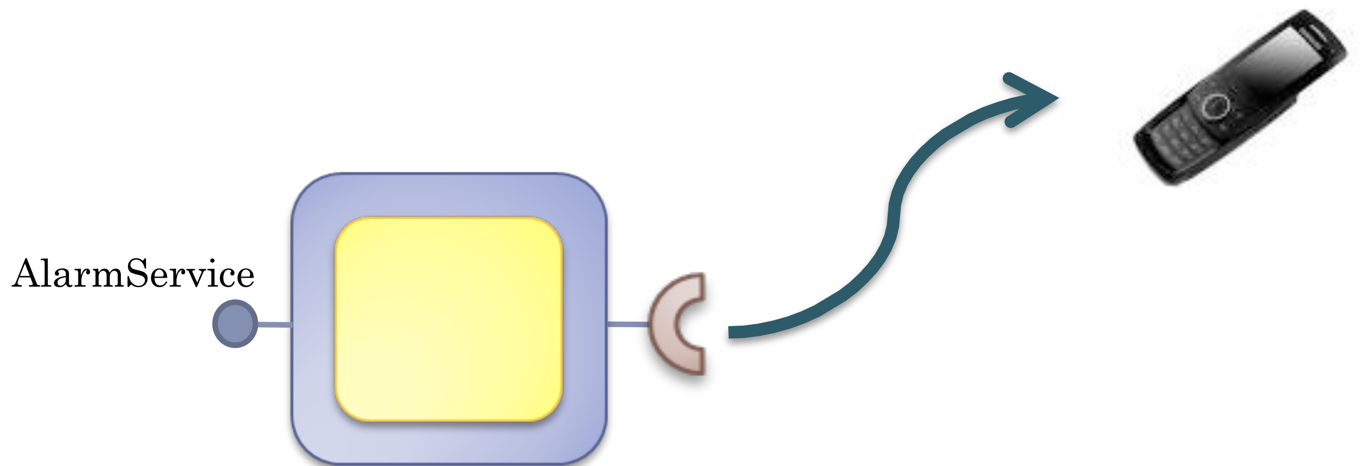
ATOMIC COMPONENT

- Atomic components deal with the following requirements
  - A simple development model,
  - Hiding dynamism,
  - Managing state

- Characteristics
  - Centered on the notion of service component
    - With required and provided services
    - Partial architectural vision
  - It is a component type with a concrete implementation, supporting configurations

Example Of Atomic Component Description

```
@Component
@Provides
public class AlarmServiceImpl implements AlarmService {
    @Requires
    private MessageSender m_sender;
    public void sendAlarm(String message) {
        System.out.println(m_sender.send(message));
    }
}
```



EXAMPLE OF ATOMIC COMPONENT
SERVICE DEPARTURE MANAGEMENT

```
@Component
@Provides
public class AlarmServiceImpl implements AlarmService {
    @Requires
    private MessageSender m_sender;
    public void sendAlarm(String message) {
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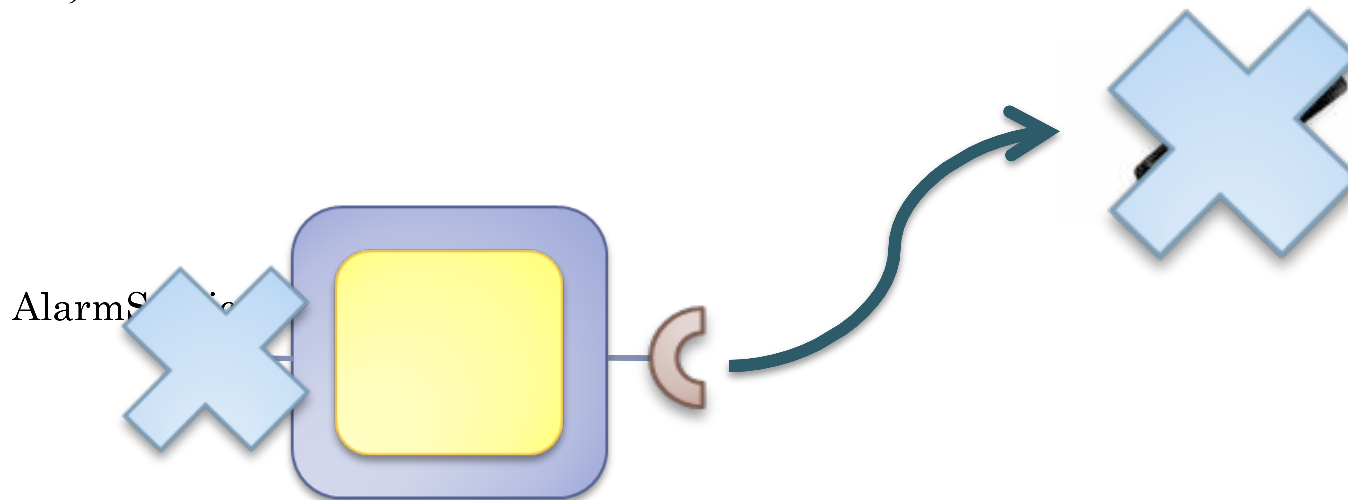

Example Of Atomic Component
Service Arrival Management

```
@Component
@Provides
public class AlarmServiceImpl implements AlarmService {
    @Requires
    private MessageSender m_sender;
    public void sendAlarm(String message) {
        System.out.println(m_sender.send(message));
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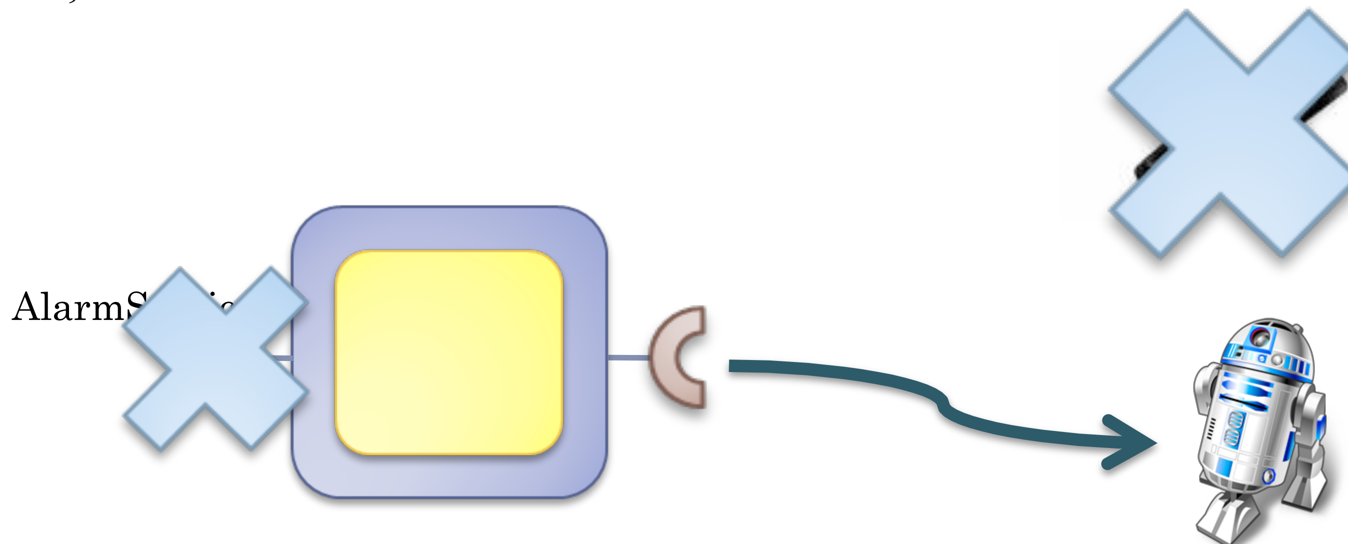
}
```

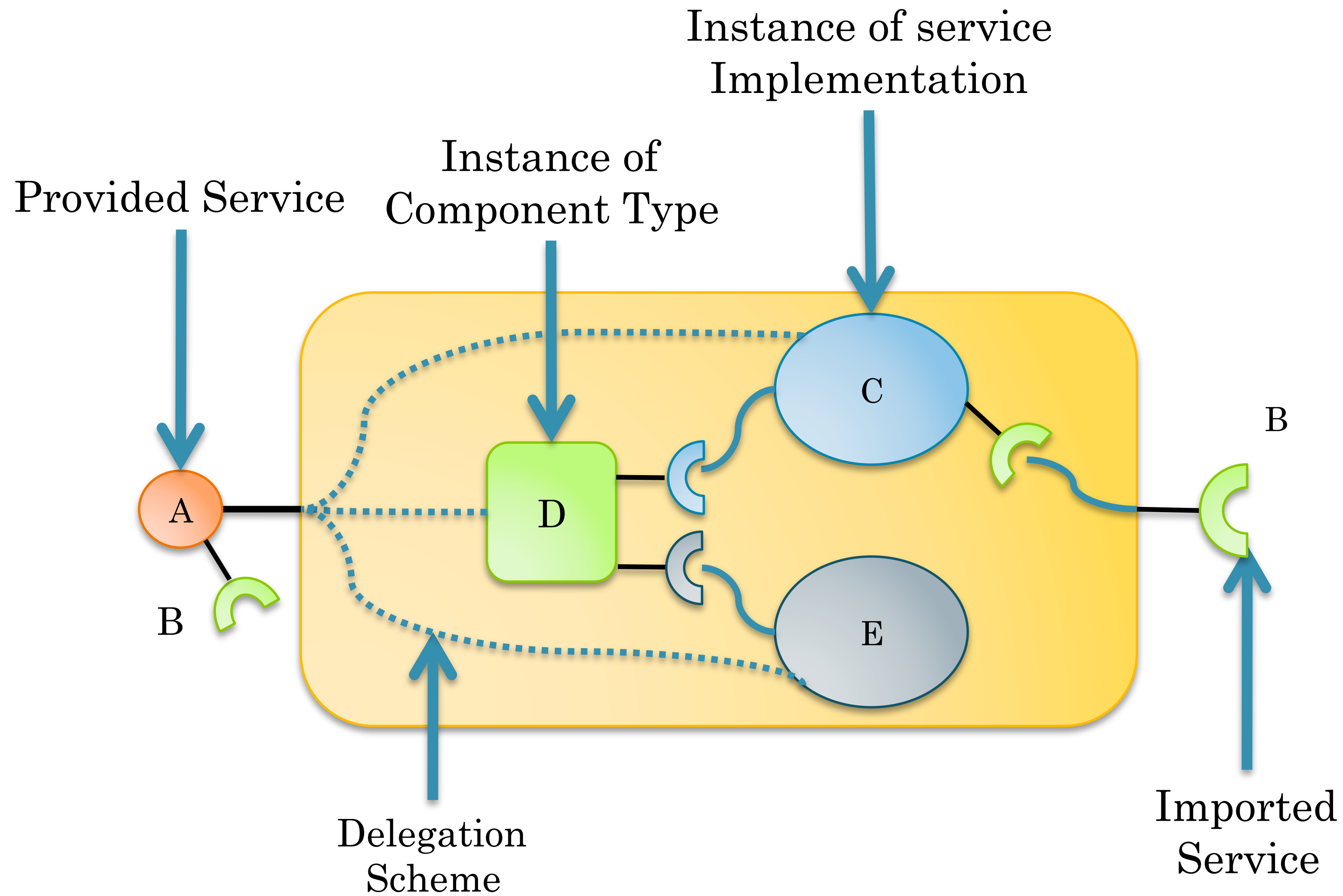


Composite Component

- An Architecture Description Language defined in terms of
  - Required Service Specifications
    - Instantiated and Imported
  - Provided Service Specifications
    - Exported and *Implemented*
  - Component Types

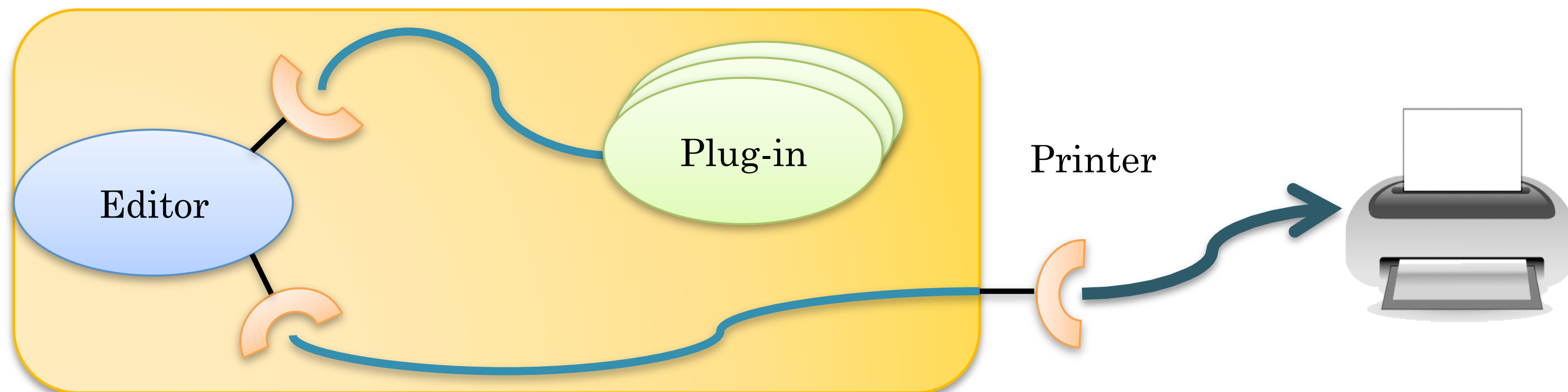
- Characteristics
  - Application concept and vertical composition
  - Implementation evolution and substitution
  - Context-awareness

Composite Component Description



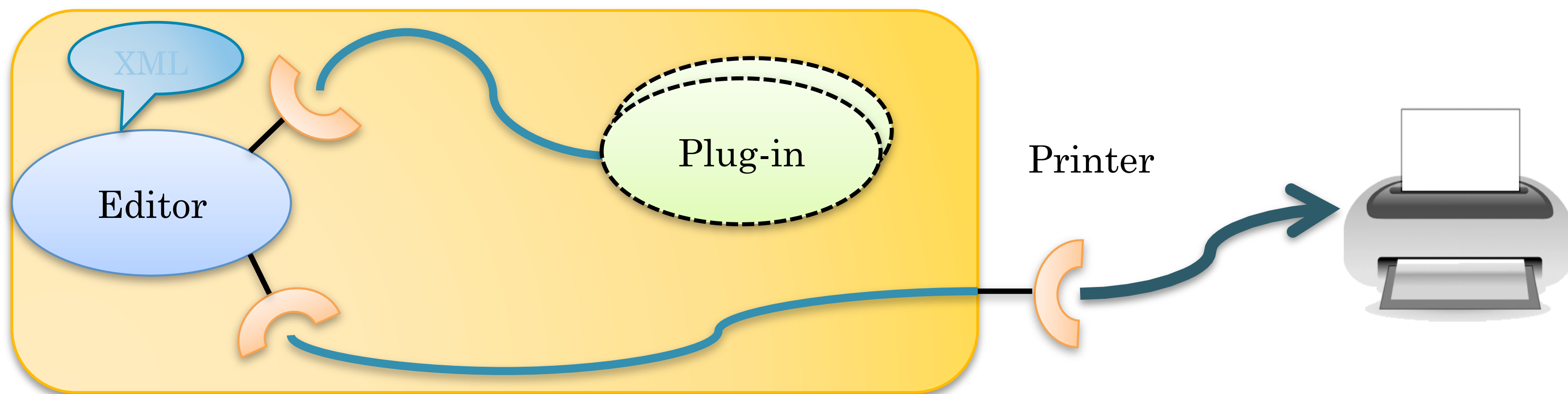
Composite Component Example

```
<composite name="Editor1">
<subservice action="instantiate"
      specification="…Editor"/>
<subservice action="instantiate"
      specification="… Plugin"     aggregate="true" />
<subservice action="import"
      specification="…Printer"   optional="true"/>
</composite>
```



Composite Component
Context-Awareness Example

```
<composite name="“Editor2">
<subservice action="instantiate“
        specification=“… Plugin“      aggregate="true"
        filter="(type=${my.type}) "
         context-source= " local:editor" />
<subservice action="instantiate“
        specification=“…Editor“/>
<subservice action="import“
        specification=“…Printer“   optional="true”/>
</composite>
```



Composite Component
Context-Awareness Example

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<composite name="Editor2">
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      filter="(type=${my.type}) "
      context-source= " local:editor" />
<subservice action="instantiate"
      specification="...Editor"/>
<subservice action="import"
      specification="...Printer"   optional="true"/>
</composite>
```
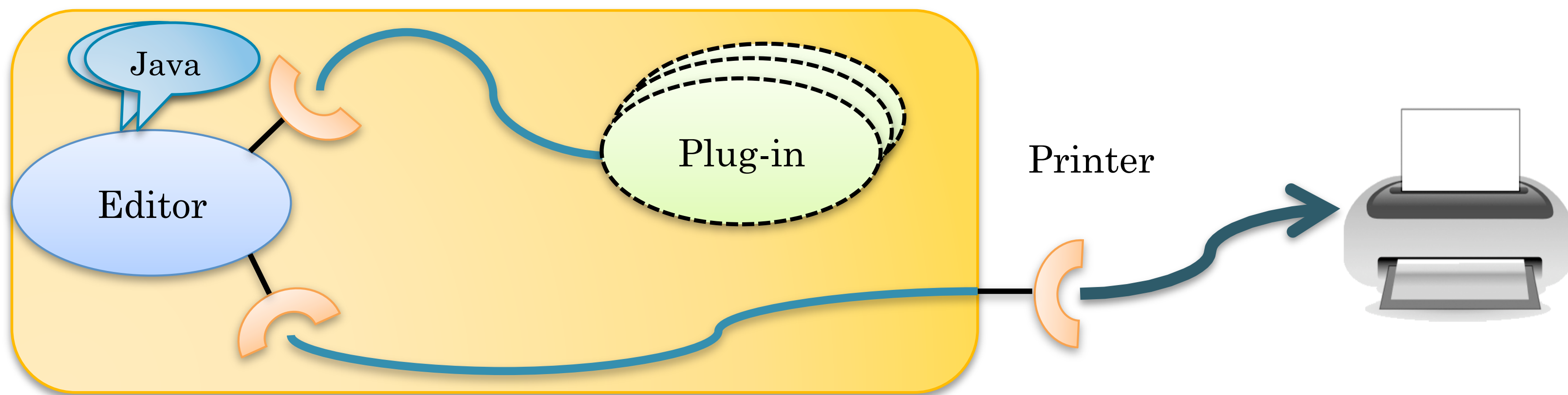
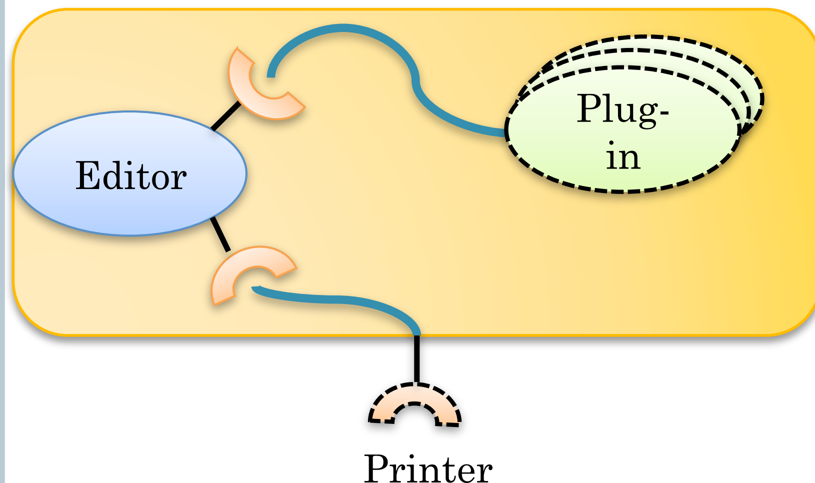



Composite Component
Context-Awareness Example

- The printer can also become context-aware
  - Select the of the closest printer

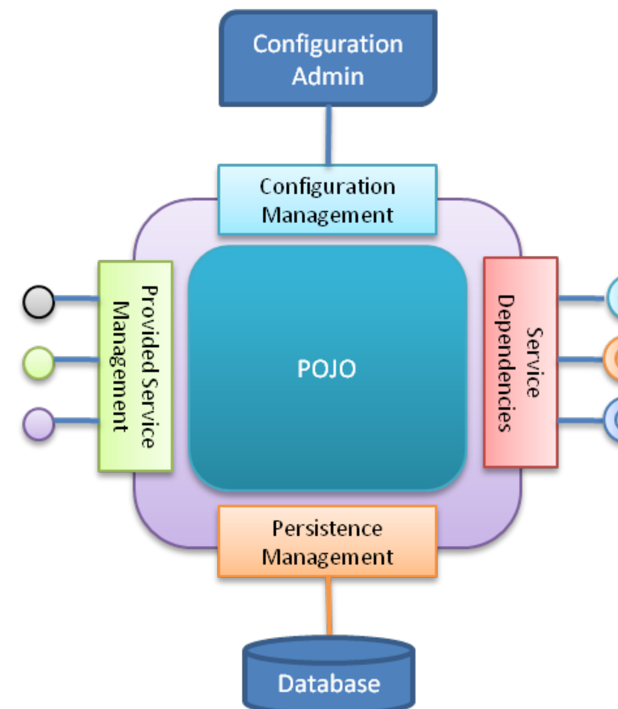



```
<composite name="Editor3">
<subservice action="instantiate"
      specification="… Plugin"  aggregate="true"
      filter="(type=${my.type}) "
      context-source= " local:editor" />
<subservice action="instantiate"
      specification="…Editor"/>
<subservice action="import"
      specification="…Printer" optional="true"
      context-source="global:location-source"
      filter="(&(printer.location=$
      {current.location})(duplex=true))"
 />
</composite>
```

- To get the closest printer, the composition uses a global context-source tracking the user location

Other Features : Introspection, Reconfiguration & Extensibility

- System introspection for monitoring purposes
- System reconfiguration
- Supports extensions



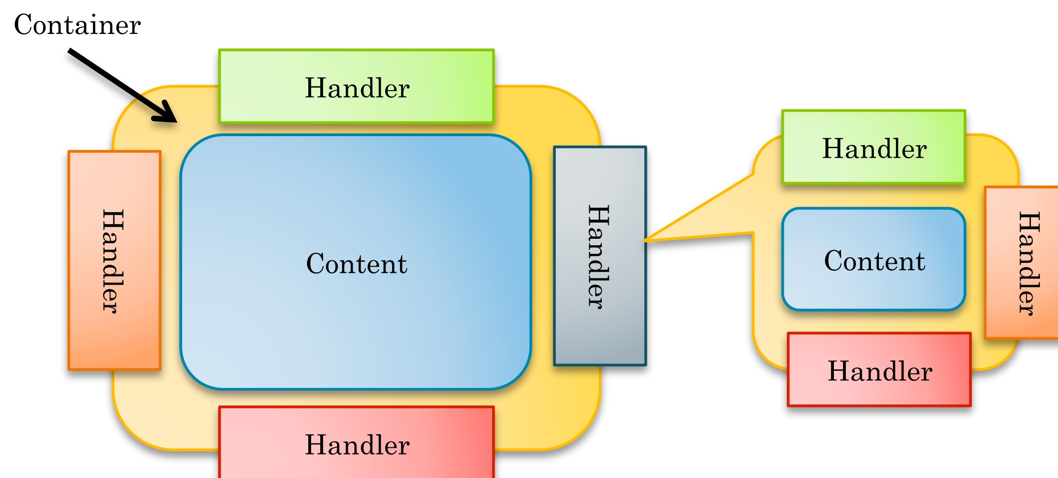
Synthesis

- Atomic Components provide a simple dev. model
  - Hiding dynamism
  - Hiding service-based interactions
  - Hiding synchronization
- Composites provide an ADL for dynamic applications
  - Based on services
  - Supporting evolution dynamism, environmental changes and context changes
- Noteworthy features
  - Introspection, reconfiguration, extensions support

Implementation & Validation

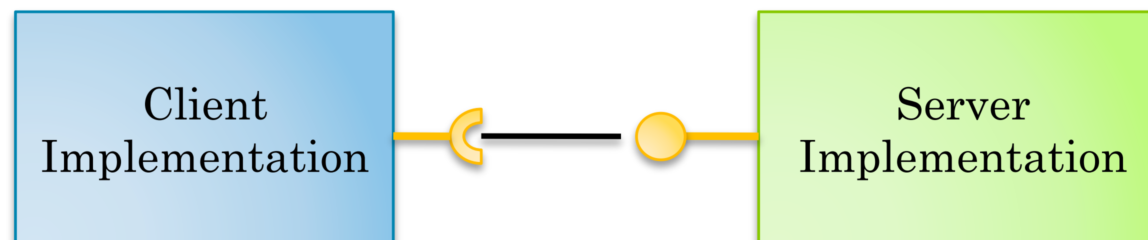
Implementation

- iPOJO implementation main features
  - *Bytecode* manipulation
  - Extensible through *Handlers*
    - Handlers are iPOJO instances
    - Natively support dynamism
  - Heavy use of threads and synchronization constructions
  - On top of OSGi R4.0

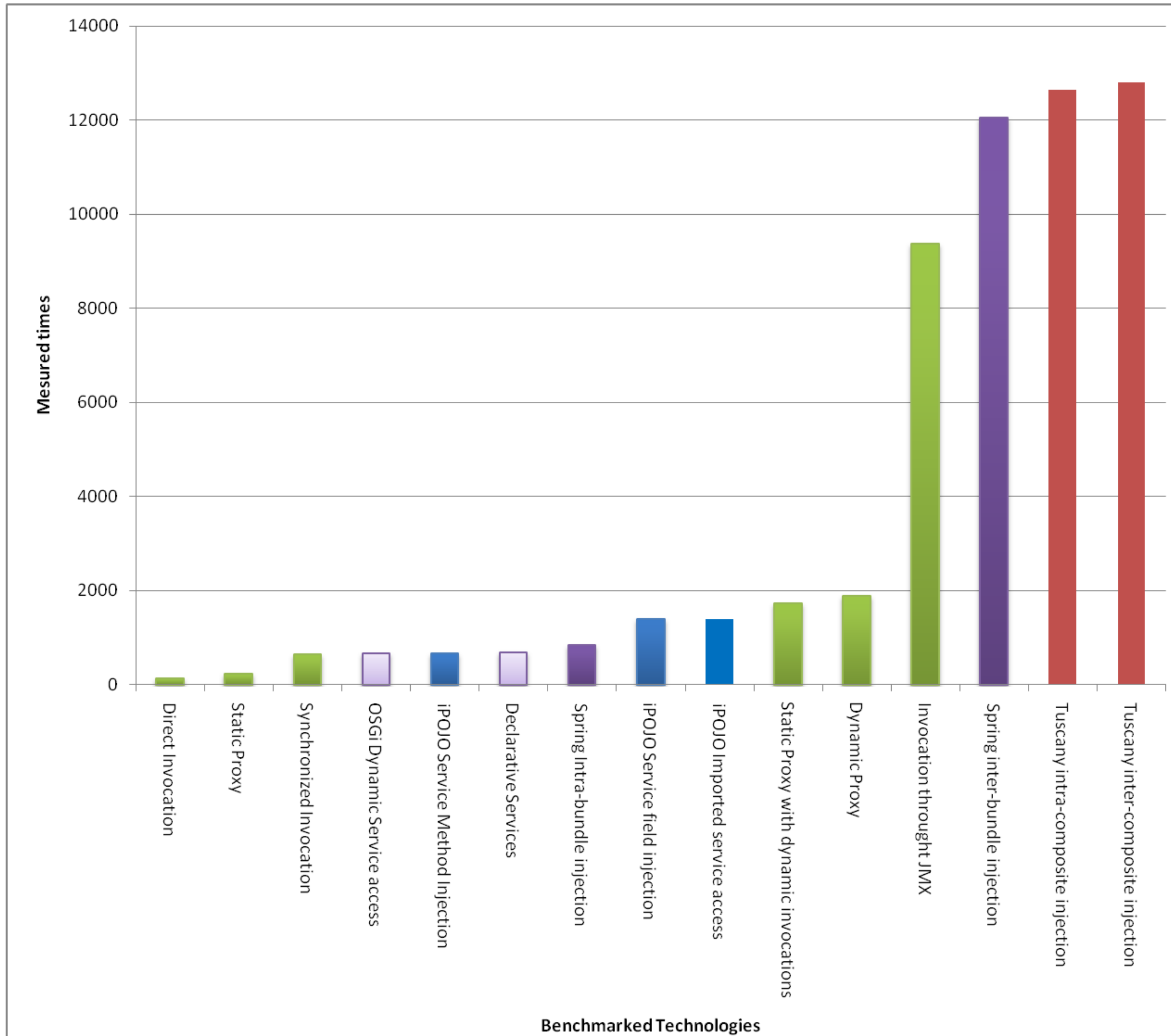


VALIDATION
BENCHMARK

- Impact on the code size
  - According to the application, iPOJO can drastically reduce the number of line of code
- Several benchmarks were executed
  - Startup time of large applications (*vs.* OSGi)
    - Facing the "Event Storm"
    - OSGi : 512 687 ms / iPOJO: 491 543 ms
  - Service Access
    - Analyze service injection against other injection frameworks



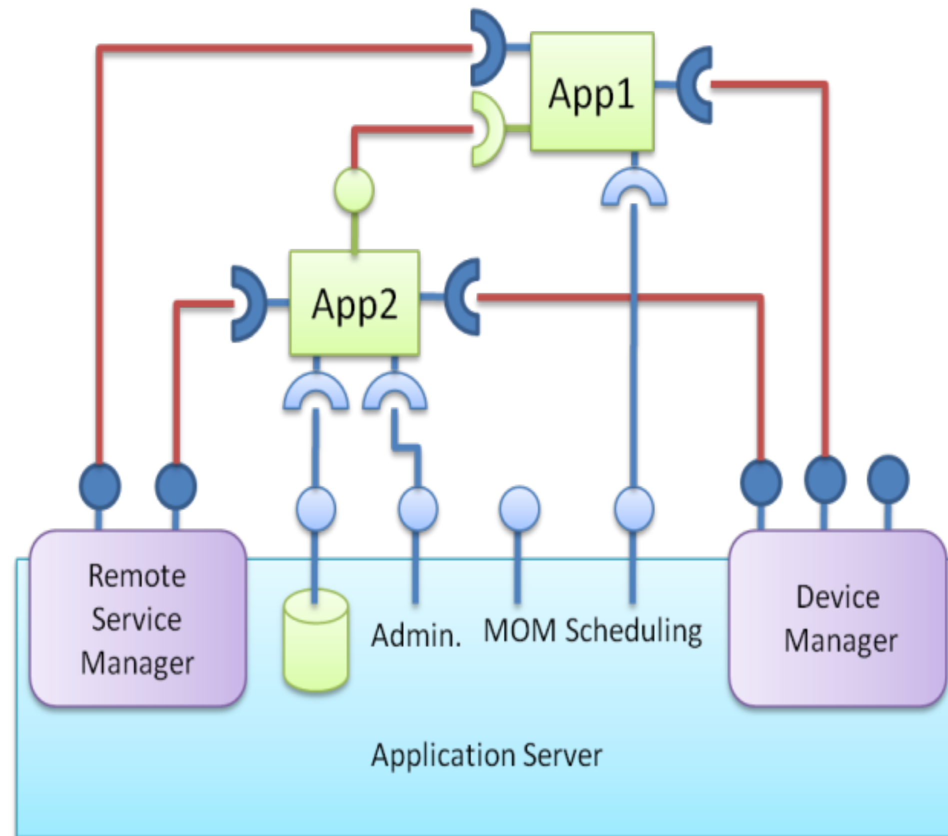
Injection Benchmark Results



RESIDENTIAL GATEWAYS EXAMPLE

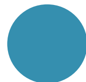
- OSGi/iPOJO framework is used to develop residential gateways.

- Requirements:
  - Dynamism management
  - Extensibility
  - Composition and Isolation

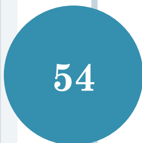


Java EE Server Example

- iPOJO is used in the JOnAS Java EE server
- Requirements
  - Dynamism management
  - Non-intrusive development model



Conclusion & Perspectives



Main Contributions

- iPOJO proposes a new way to design, develop and execute dynamic applications
- A model and an associated runtime
- Provides a simple development model
- Provides a hierarchical composition language
- Provides introspection, reconfiguration and extensibility mechanisms

Availability

- iPOJO is hosted on Apache Felix
  - Every described feature is implemented!

- Additional provided tools
  - Integration in the build process
    - Ant, Maven
  - A command dumping instance architecture data
  - A test framework (based on Junit)

http://www.apache.org/

PERSPECTIVES

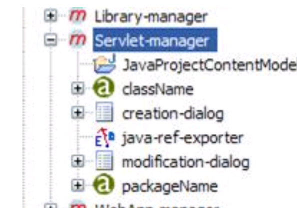
- Apply iPOJO principles on different technologies
  - Principles can also be used on the top of other technologies than OSGi™
  - However, rare are the frameworks providing the required underlying functionalities
- Deployment support
  - How to ease the deployment of dynamic applications?
- Context-Aware and Autonomic Applications
  - iPOJO can be used to execute context-aware and autonomic applications
  - What are the missing features?

PERSPECTIVES

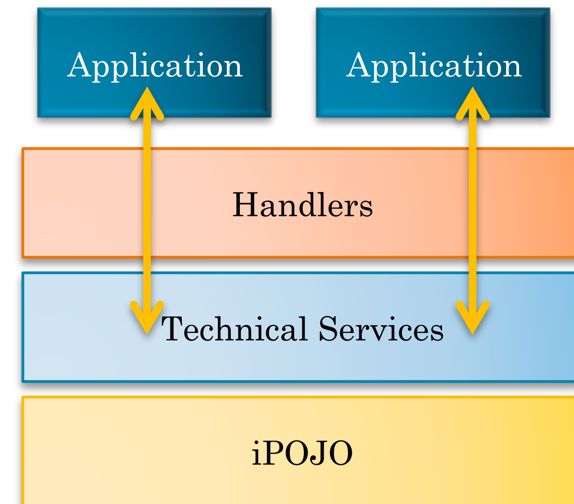
- Domain-driven application servers
  - How to provide an ADL, an IDE and an execution framework for a specific domain
  - iPOJO extensibility mechanisms can be applied to solve such problems.
  - Ongoing …

Specific Composition Language

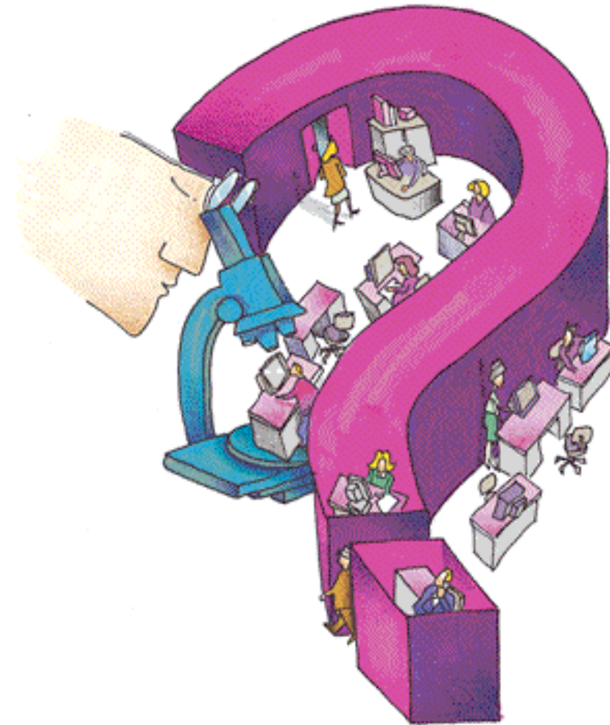
Specialized IDE



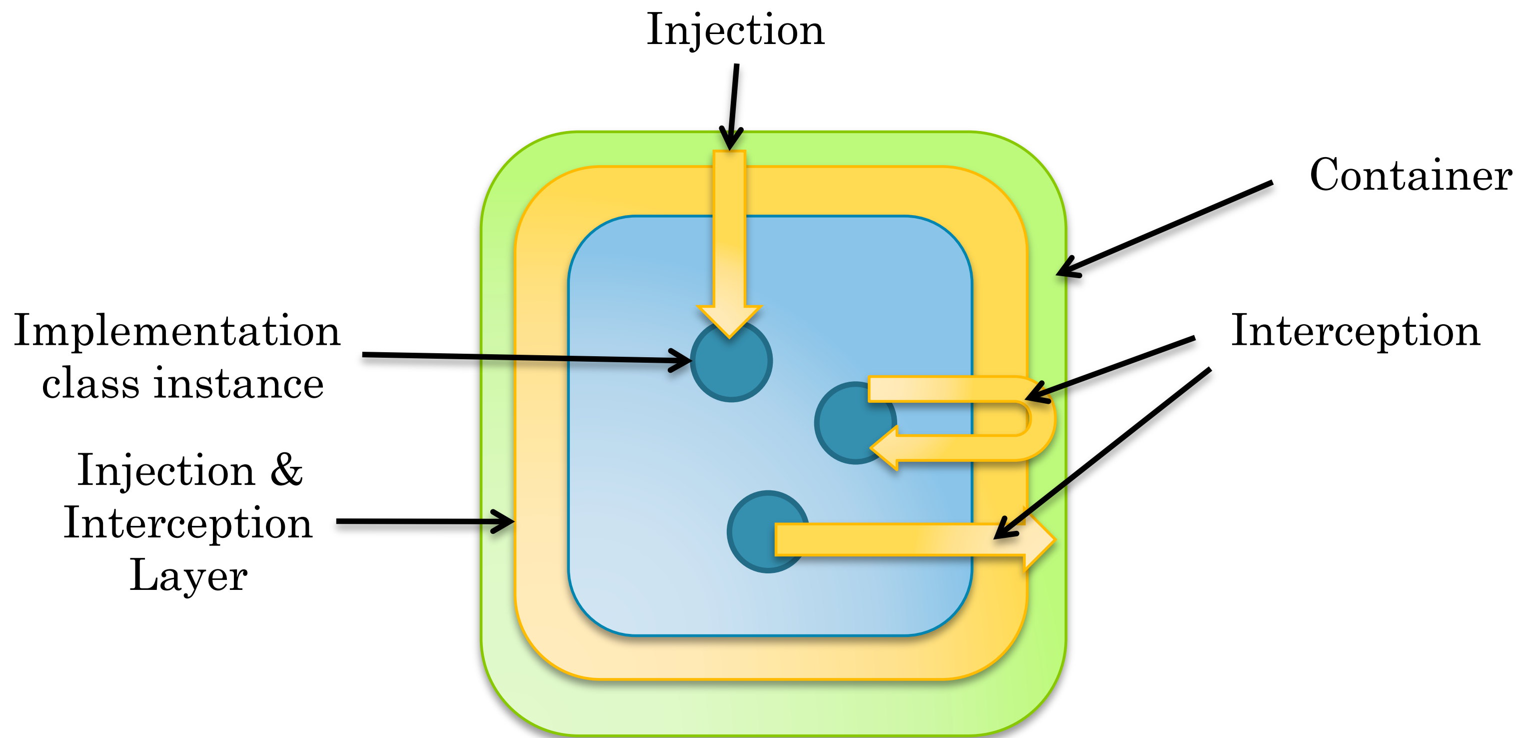
Execution Environment



Q & A



Appendix A
Interception & Injection Framework



APPENDIX A
INTERCEPTION & INJECTION FRAMEWORK

Appendix B
Lines Of Code

	Projects	LOC	Test LOC
Core	Execution Framework	7500	30000
	Manipulator	2350	
	Metadata	242	
	Annotations	105	
Composition Model	Composite	2900	8000
Tools	*“arch”*	130	8500
	Maven plugin	70	
	Ant Taks	80	
	OBR support	*2400*	
External handlers	Event Admin	300	9500
	Temporal Dependencies	250	
	Extension & Whiteboard	330	
	Administration	670	