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Architectural Degradation

The Plague of Maturing Software Systems

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Motivation

If you

design software,

implement software,

test software,

maintain software,

manage software projects,

or just use software,

you may be handling a ticking bomb.

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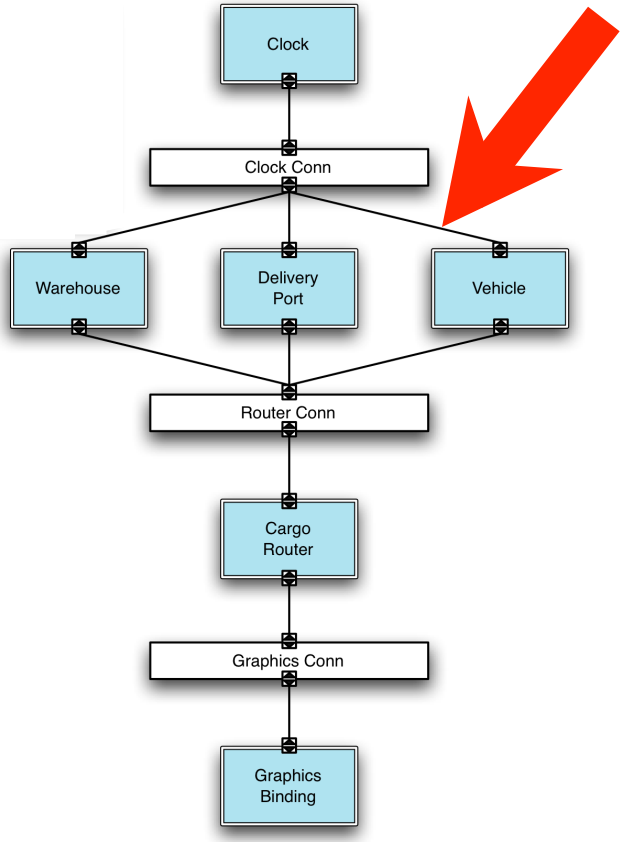
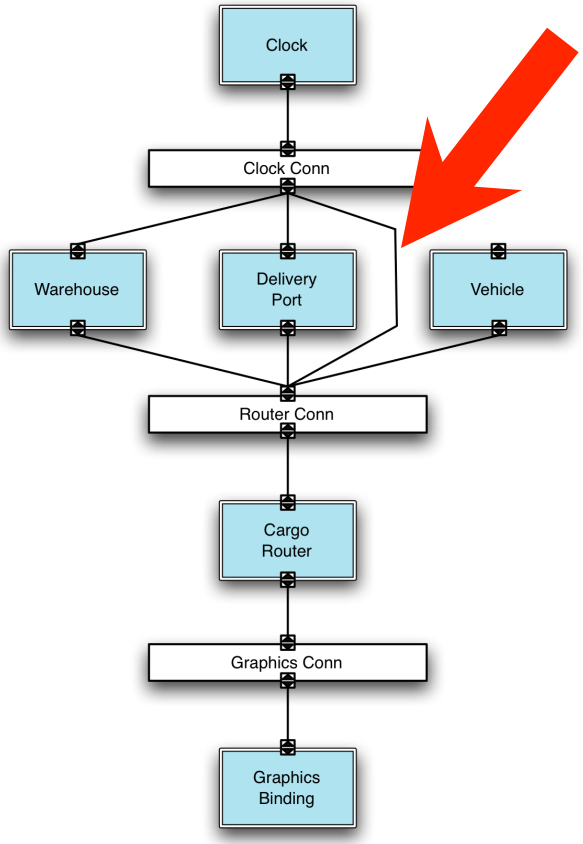
Some Terminology

- **Software architecture**
  - Set of principal design decisions *P* about a software system
- **Prescriptive architecture**
  - Set of architectural design decisions *P* made at time *t* that reflect architects' intent
  - "as designed"
- **Descriptive architecture**
  - Set of artifacts *A* that realize the design decisions *P*
  - "as implemented"

Two Architectures Side-by-Side



Prescriptive Architecture



Descriptive Architecture

What Happened?

- **Architectural drift**
  - Introduction of design decisions into a system's descriptive architecture that are not included in, encompassed by, or implied by the prescriptive architecture
- **Architectural erosion**
  - Introduction of design decisions into a system's descriptive architecture that violate its prescriptive architecture

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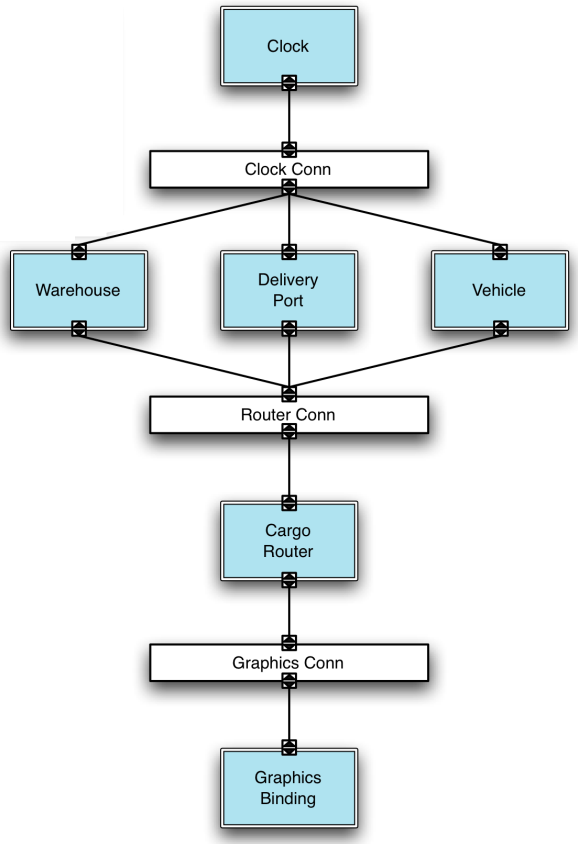
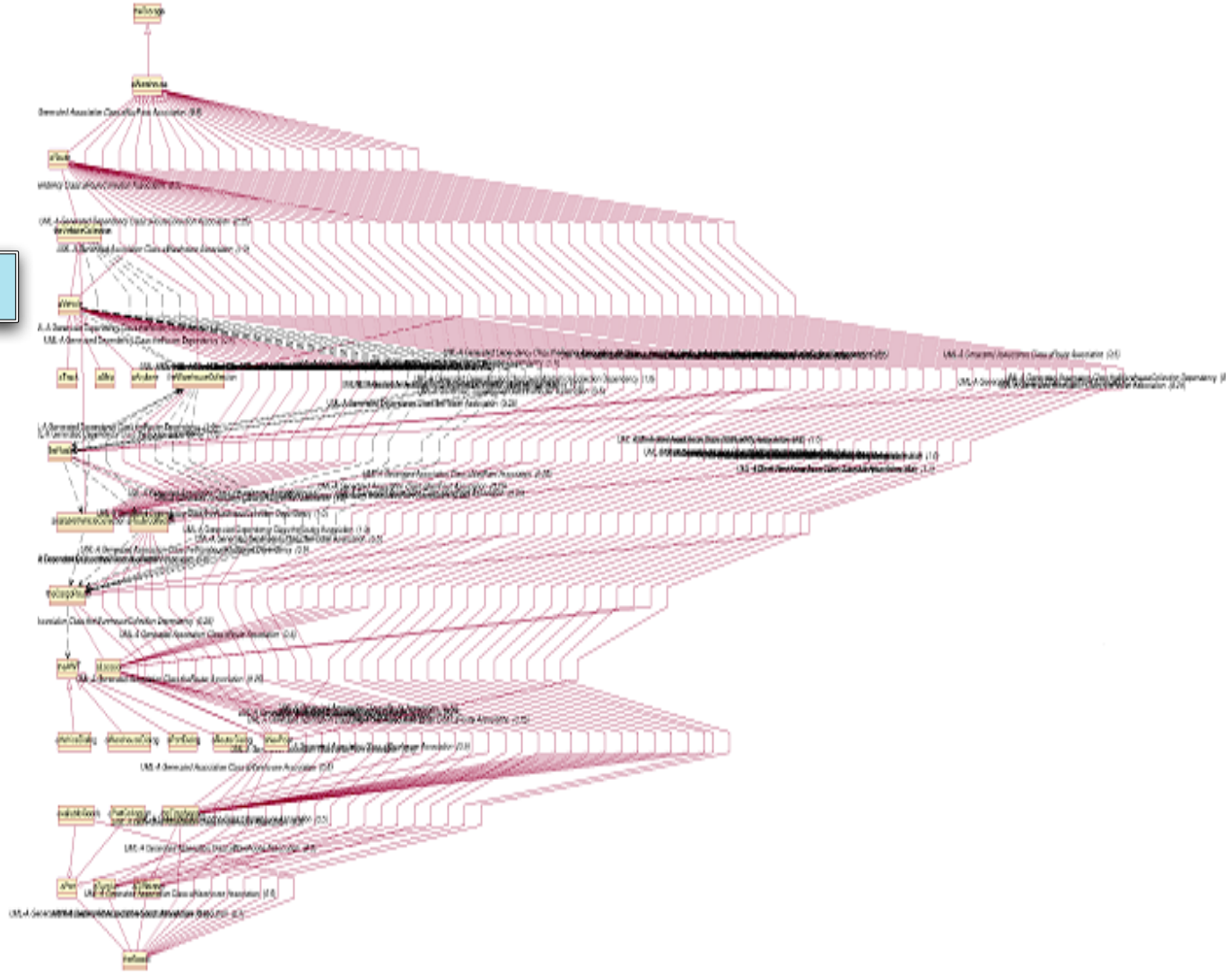
Why Do We Care?





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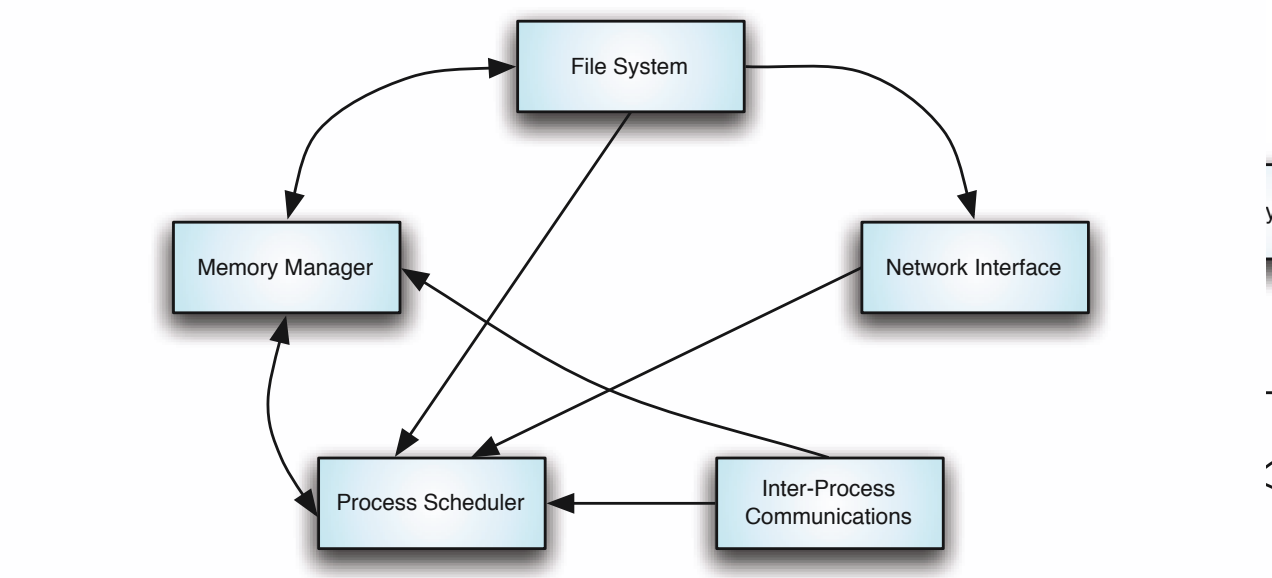
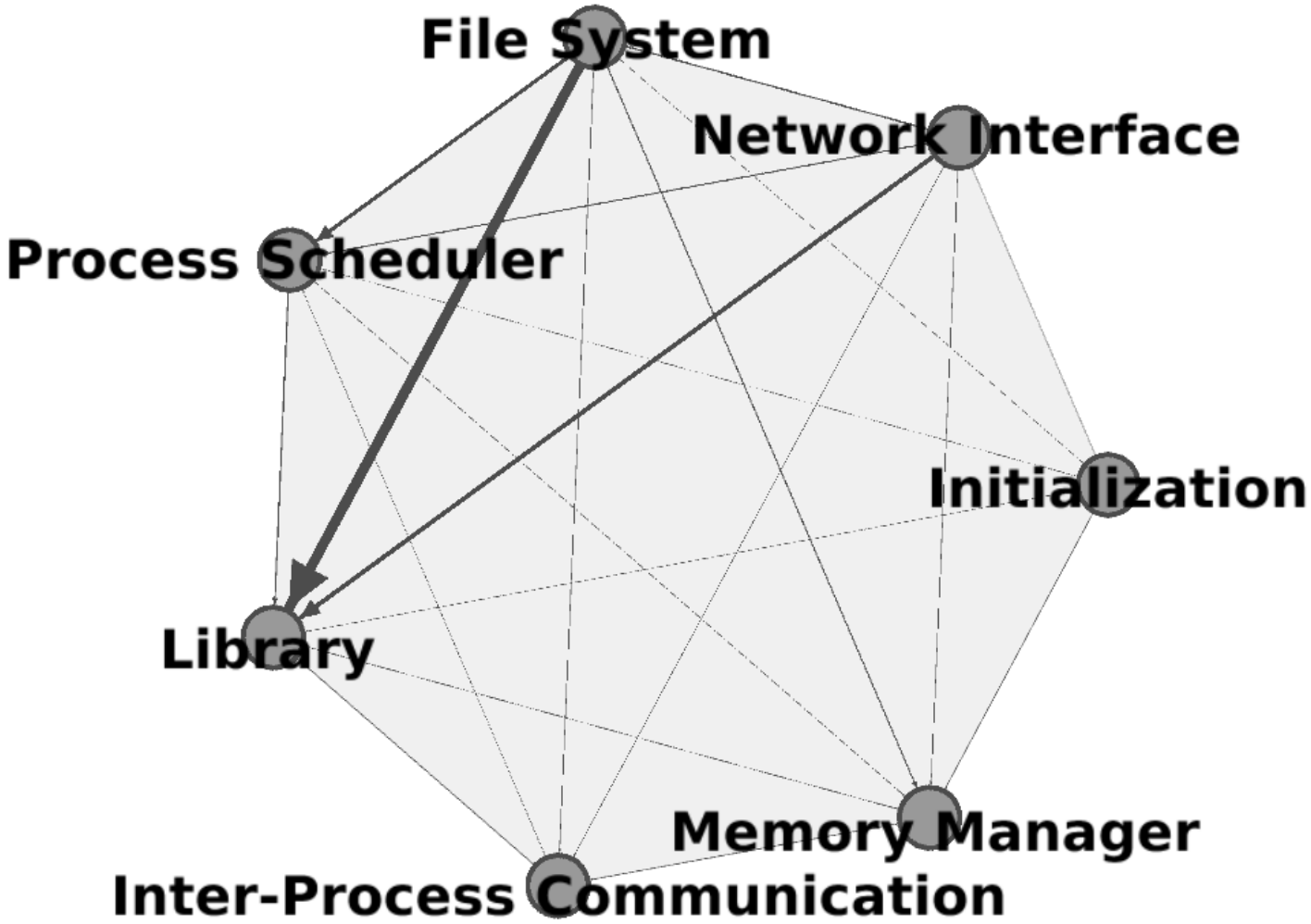
What about "Real" Examples?

Linux – Prescriptive Architecture



Linux – Descriptive Architecture

Top-Level Architecture – Another View



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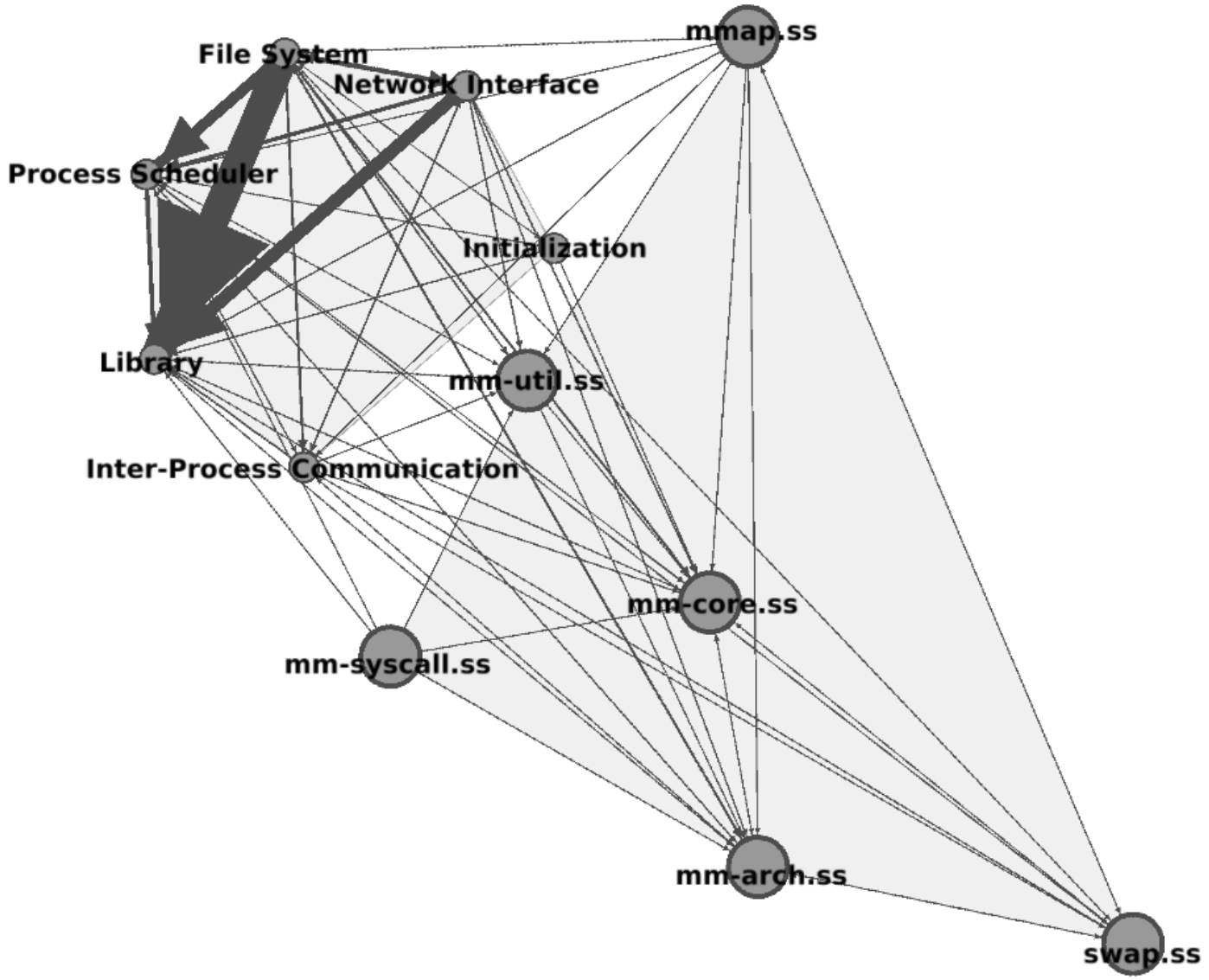
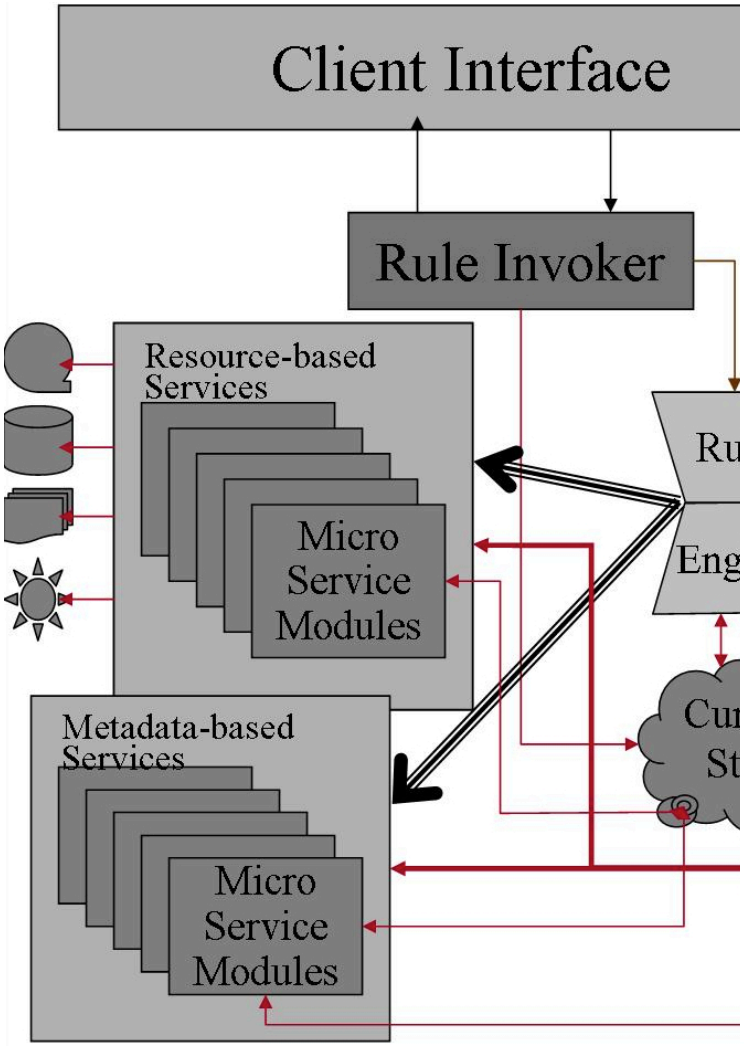
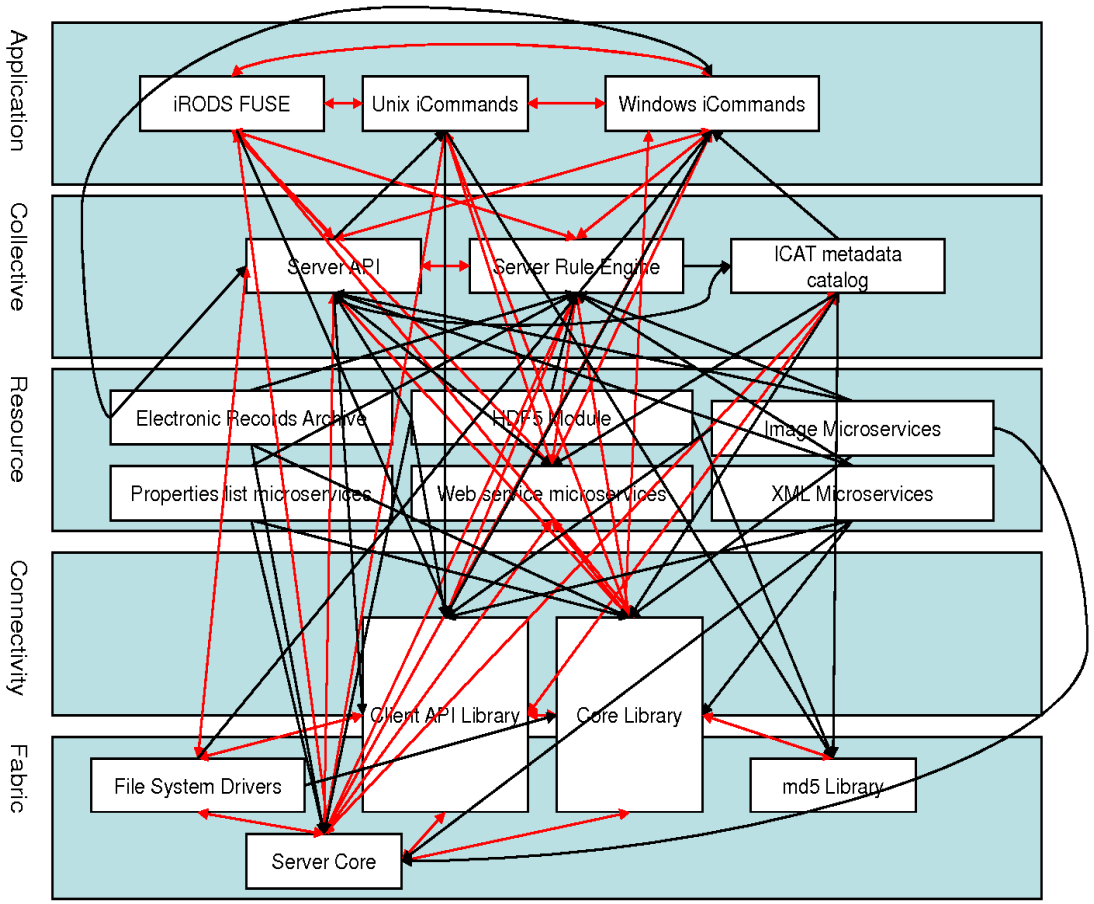
Memory Manager Subsystem



Another Example

iRODS – Prescriptive Architecture

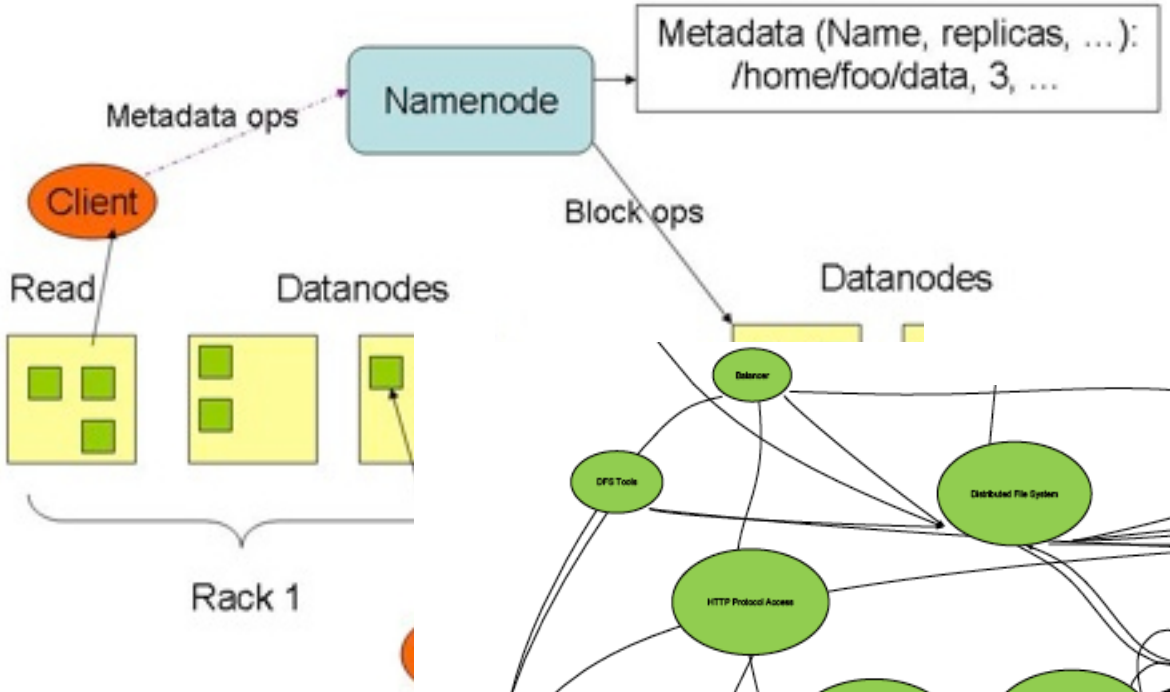


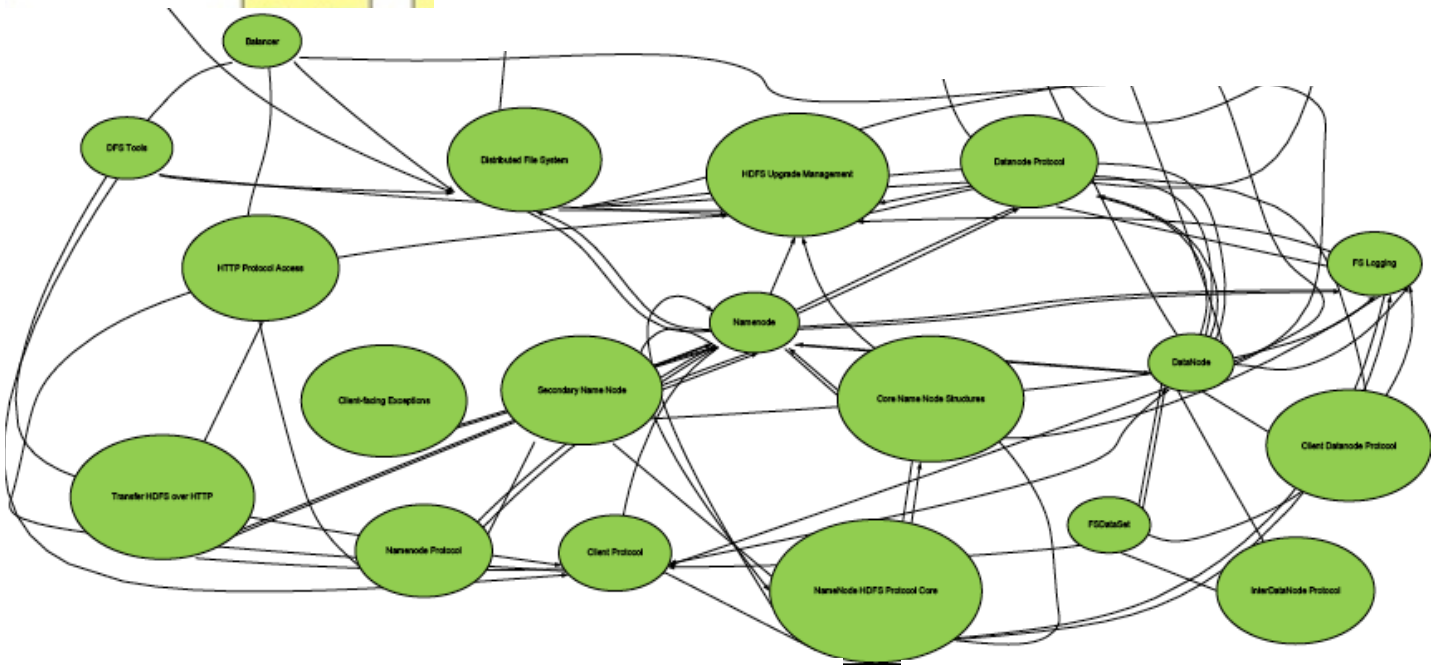


iRODS – Descriptive Architecture

And Another

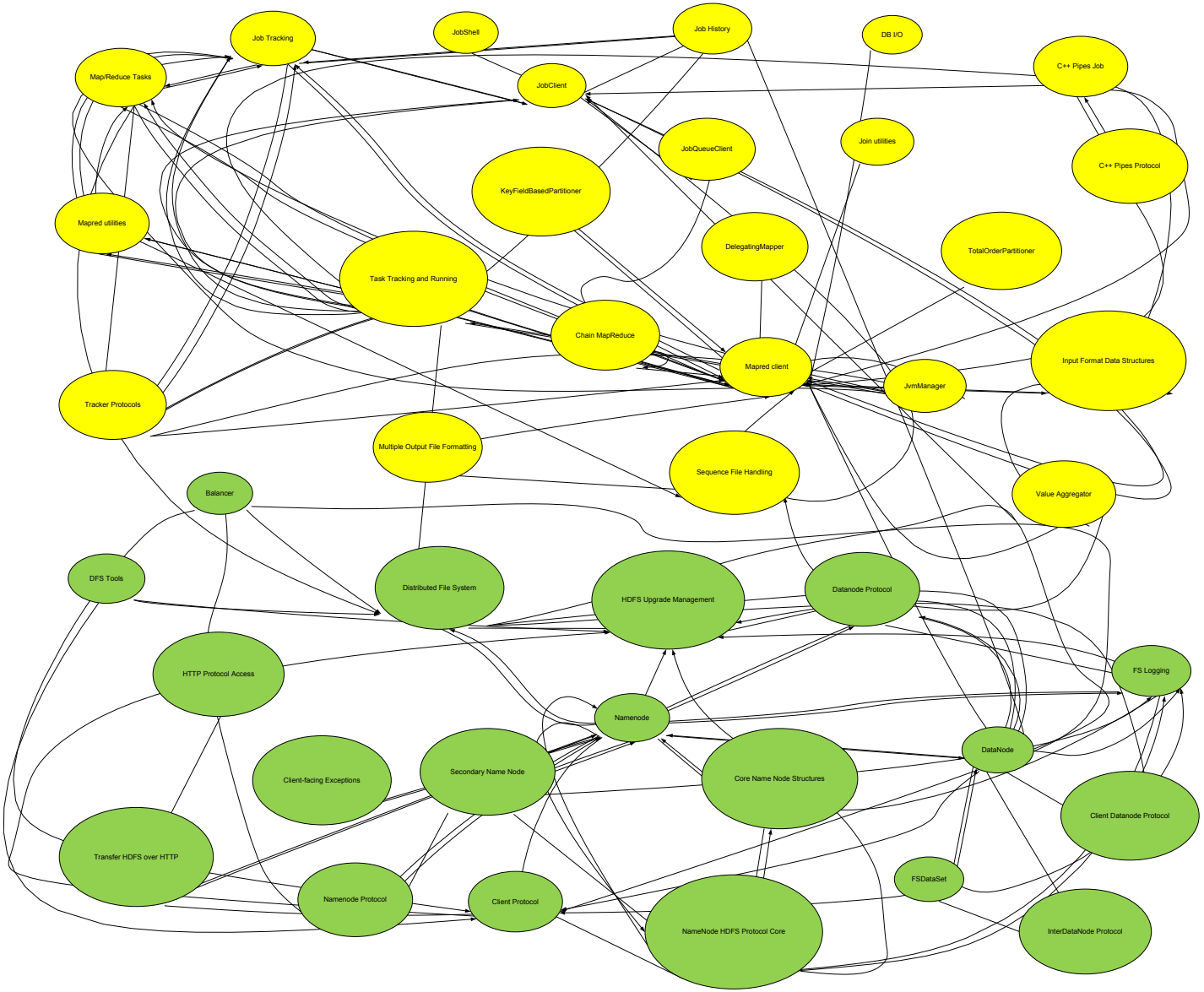
Hadoop Distributed File System – Prescriptive Architecture





HDFS – Descriptive Architecture

Hadoop – HDFS + MapReduce



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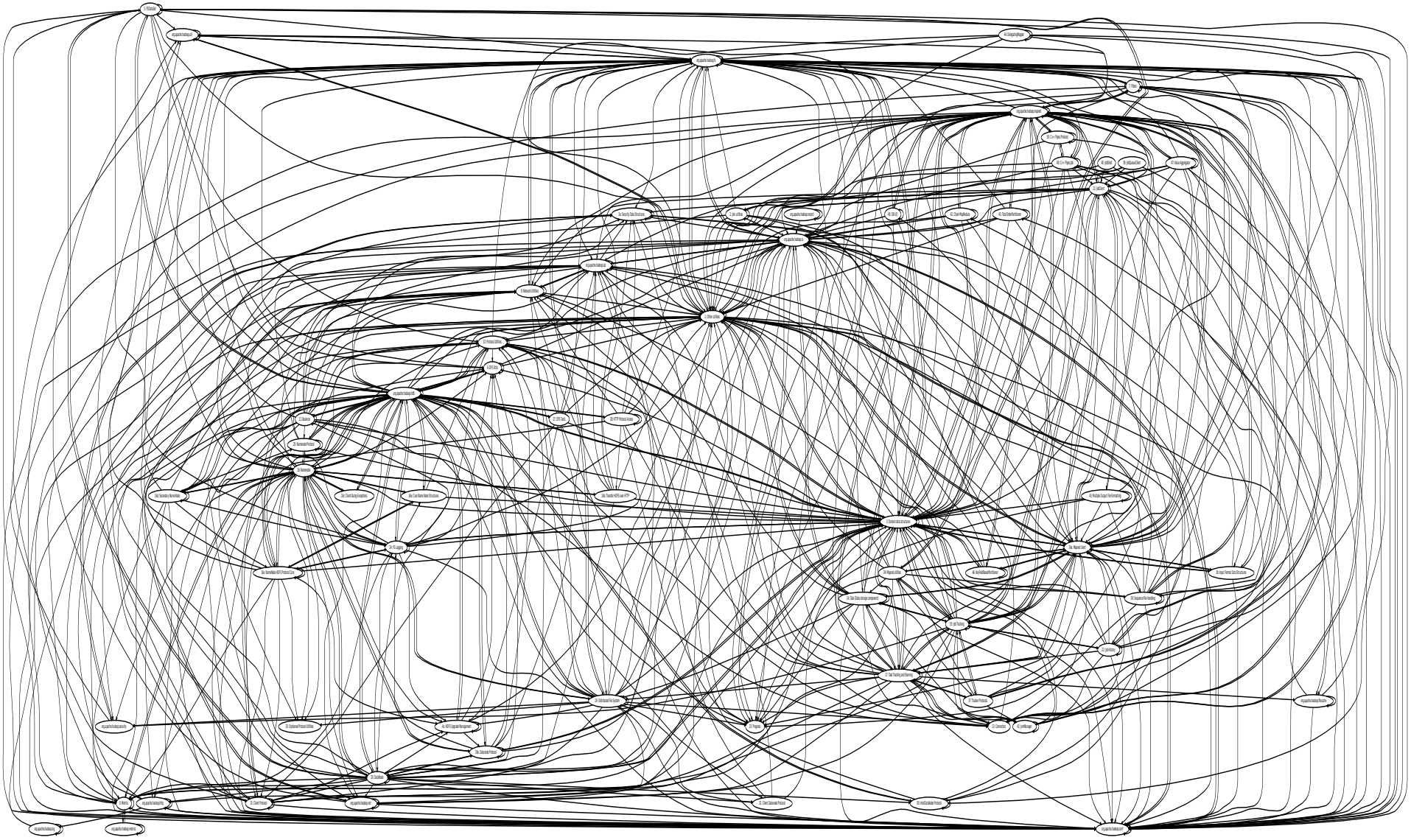
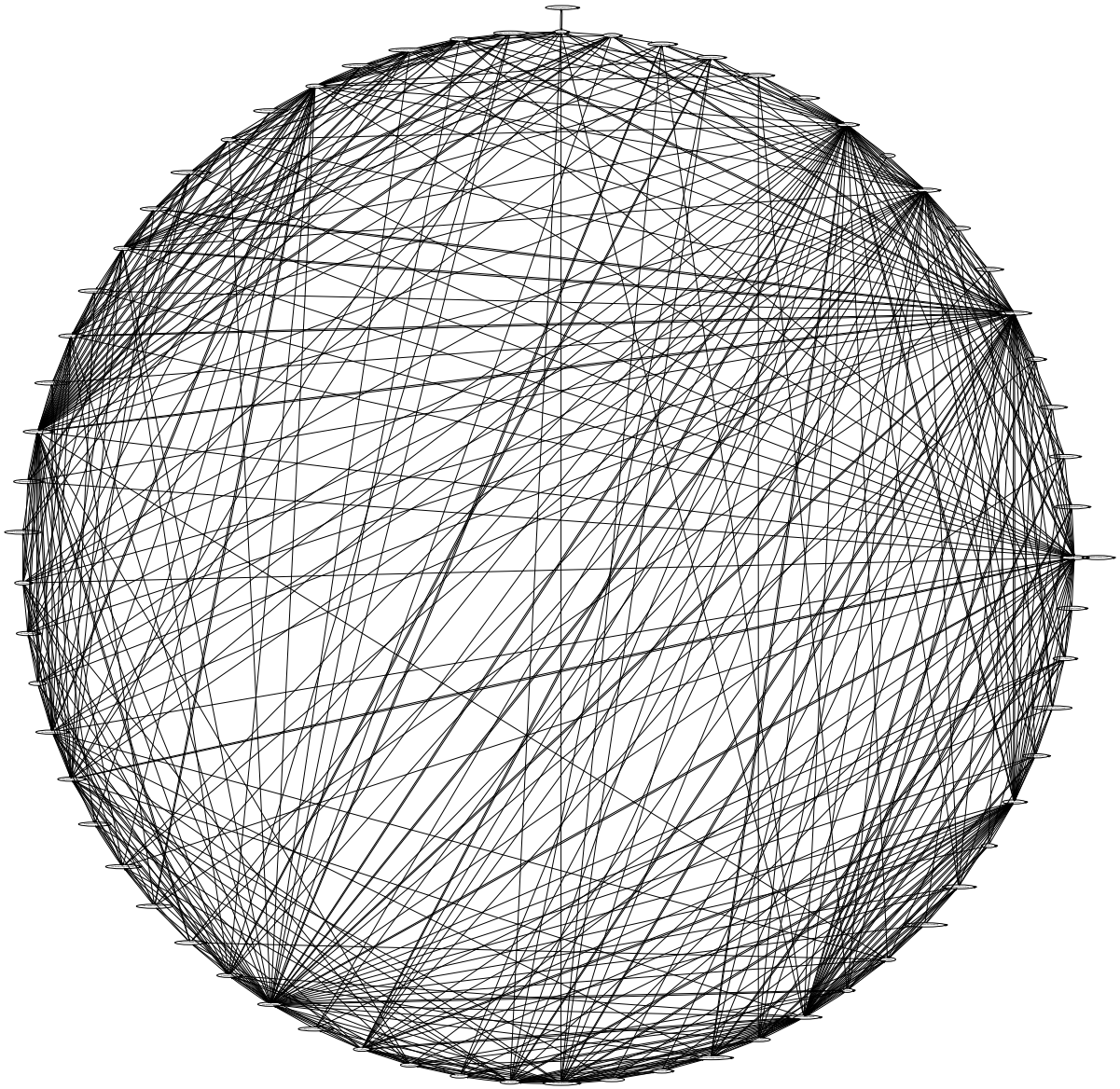
Hadoop – Complete Architecture



Hadoop – Complete Architecture
(Somewhat Beautified)



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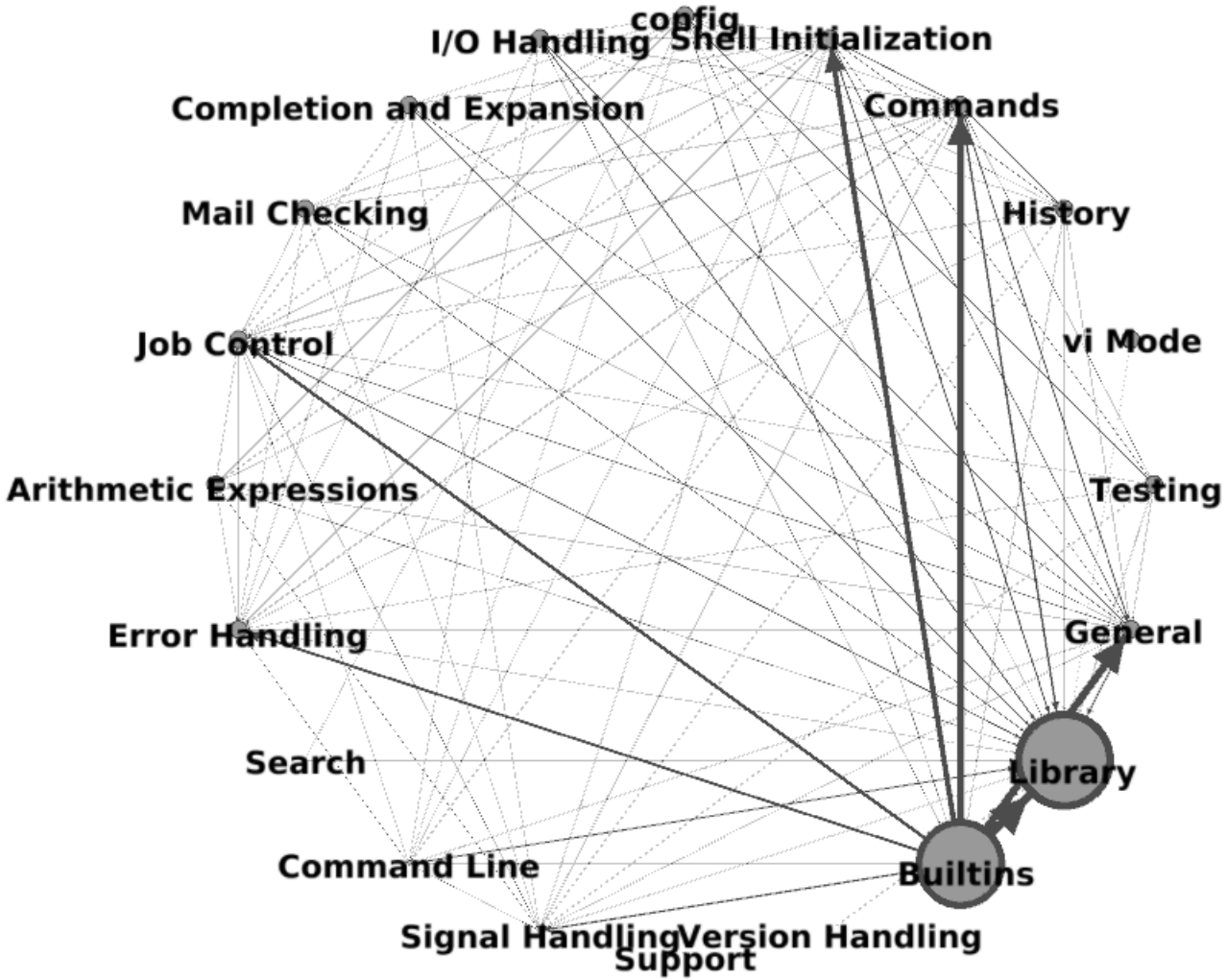
Another Example – bash

Top-Level Architecture



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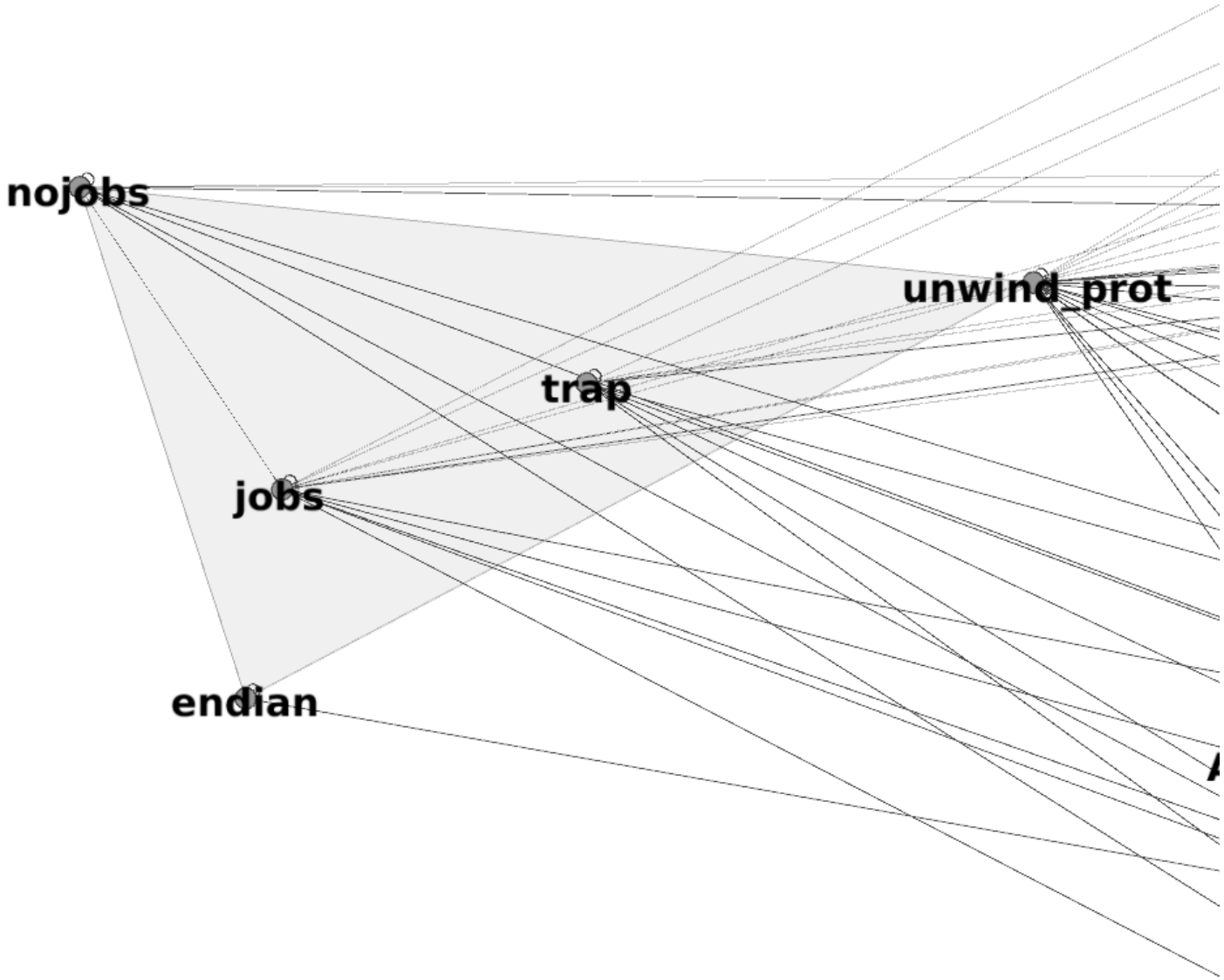
bash – Job Control Component



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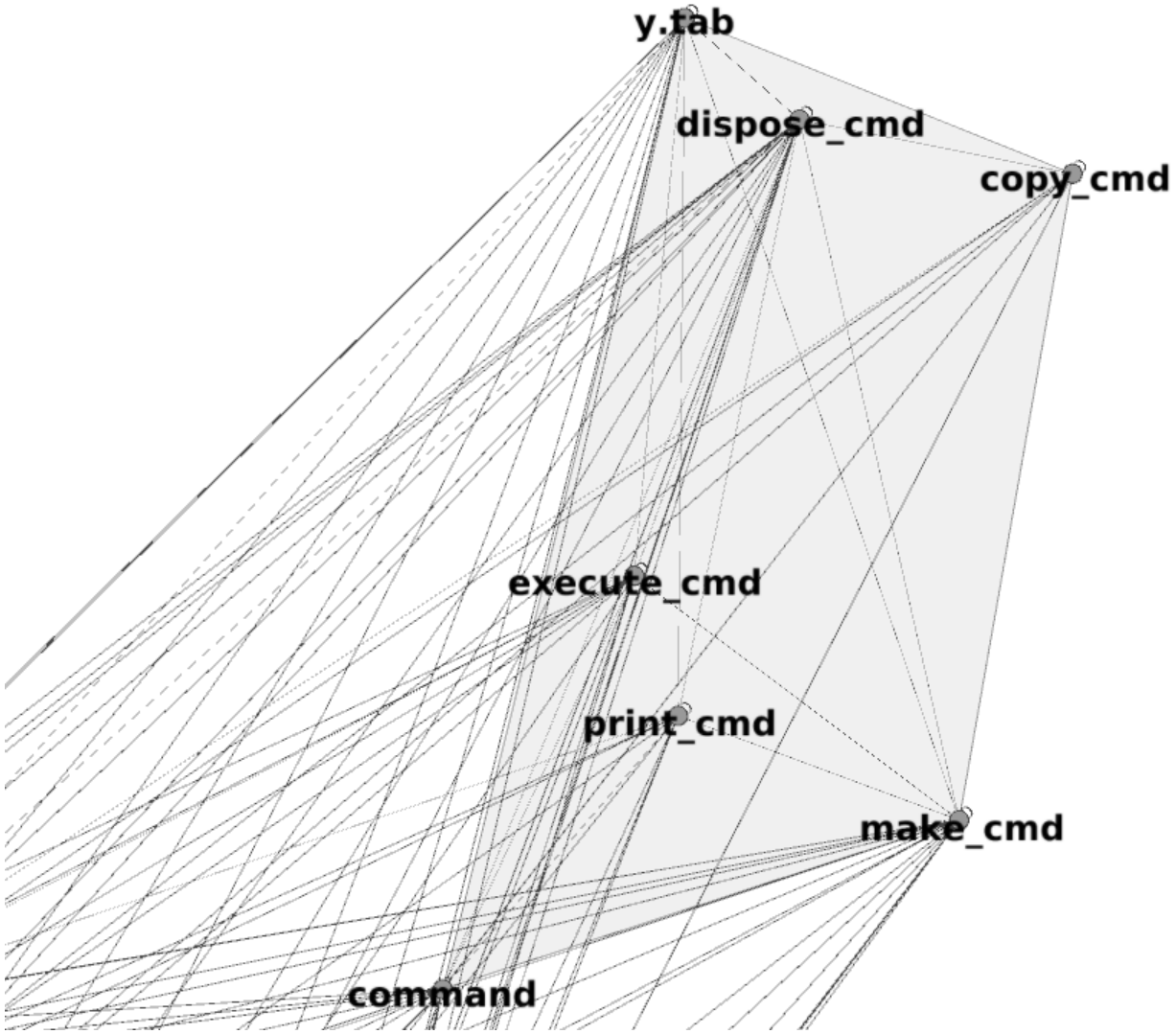
bash – Commands Component



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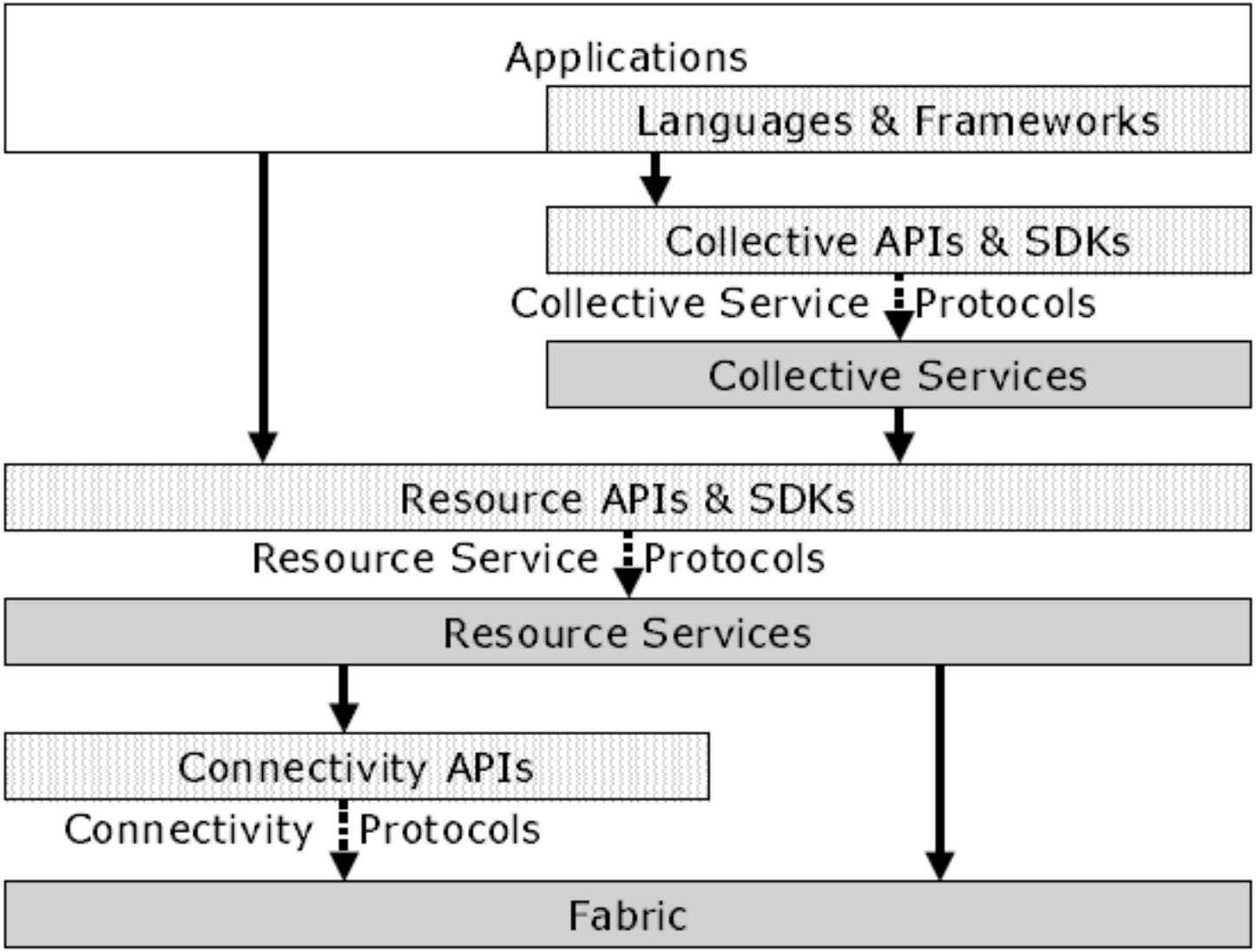
How Prevalent Is Architectural Degradation?

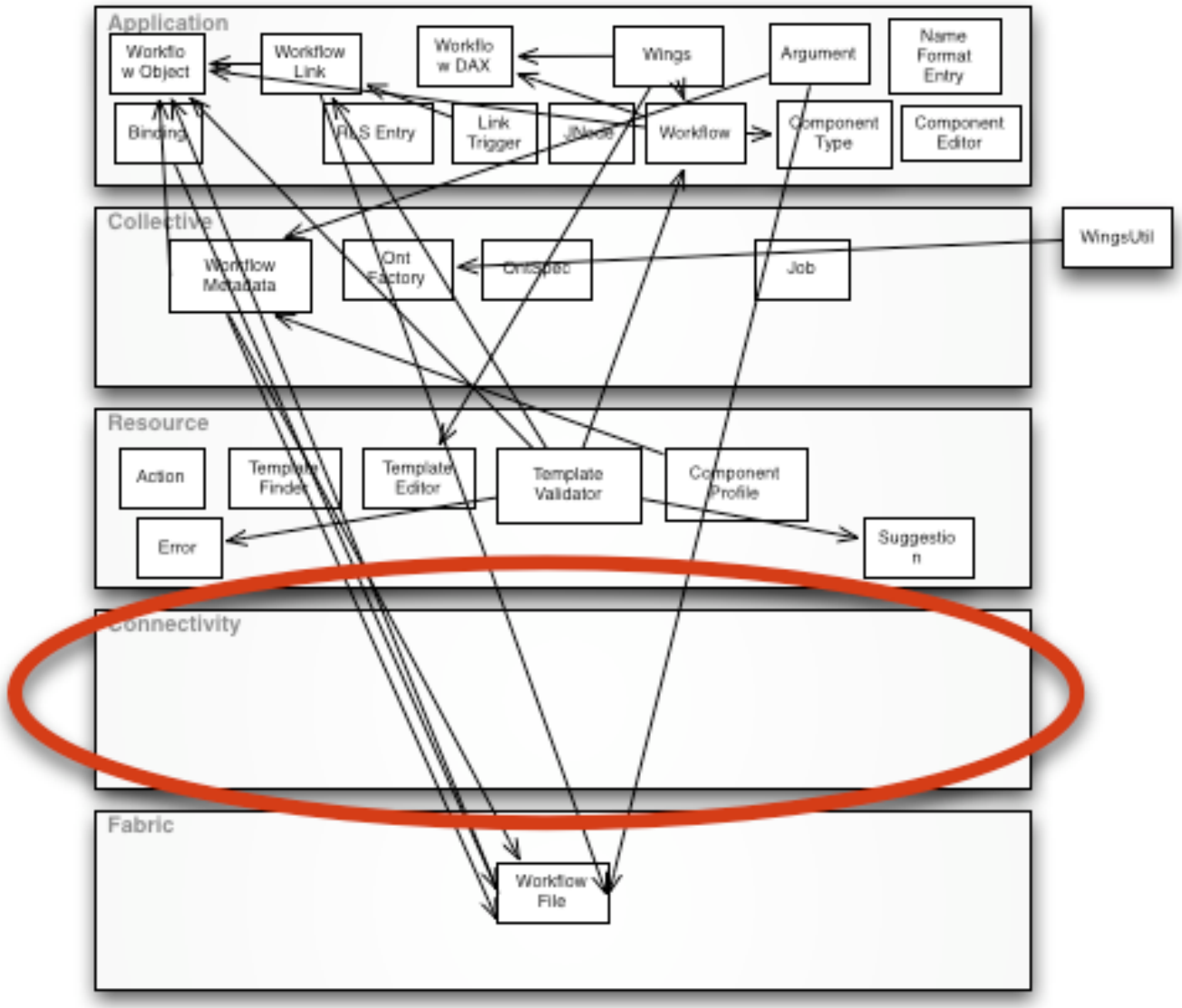
Technology	PL	KSLOC	# Modules
Alchemi	C# (.NET)	26.2	186
Apache Hadoop	Java, C/C++	66.5	1643
Apache HBase	Java, Ruby, Thrift	14.1	362
Condor	Java, C/C++	51.6	962
DSpace	Java	23.4	217
Ganglia	C	19.3	22
GLIDE	Java	2	57
Globus 4.0 (GT 4.0)	Java, C/C++	2218.7	2522
Grid Datafarm	Java, C	51.4	220
Gridbus Broker	Java	30.5	566
Jcgrid	Java	6.7	150
OODT	Java	14	320
Pegasus	Java, C	79	659
SciFlo	Python	18.5	129
iRODS	Java, C/C++	84.1	163
Sun Grid Engine	Java, C/C++	265.1	572
Unicore	Java	571	3665
Wings	Java	8.8	97

Reference Architecture for the Grid

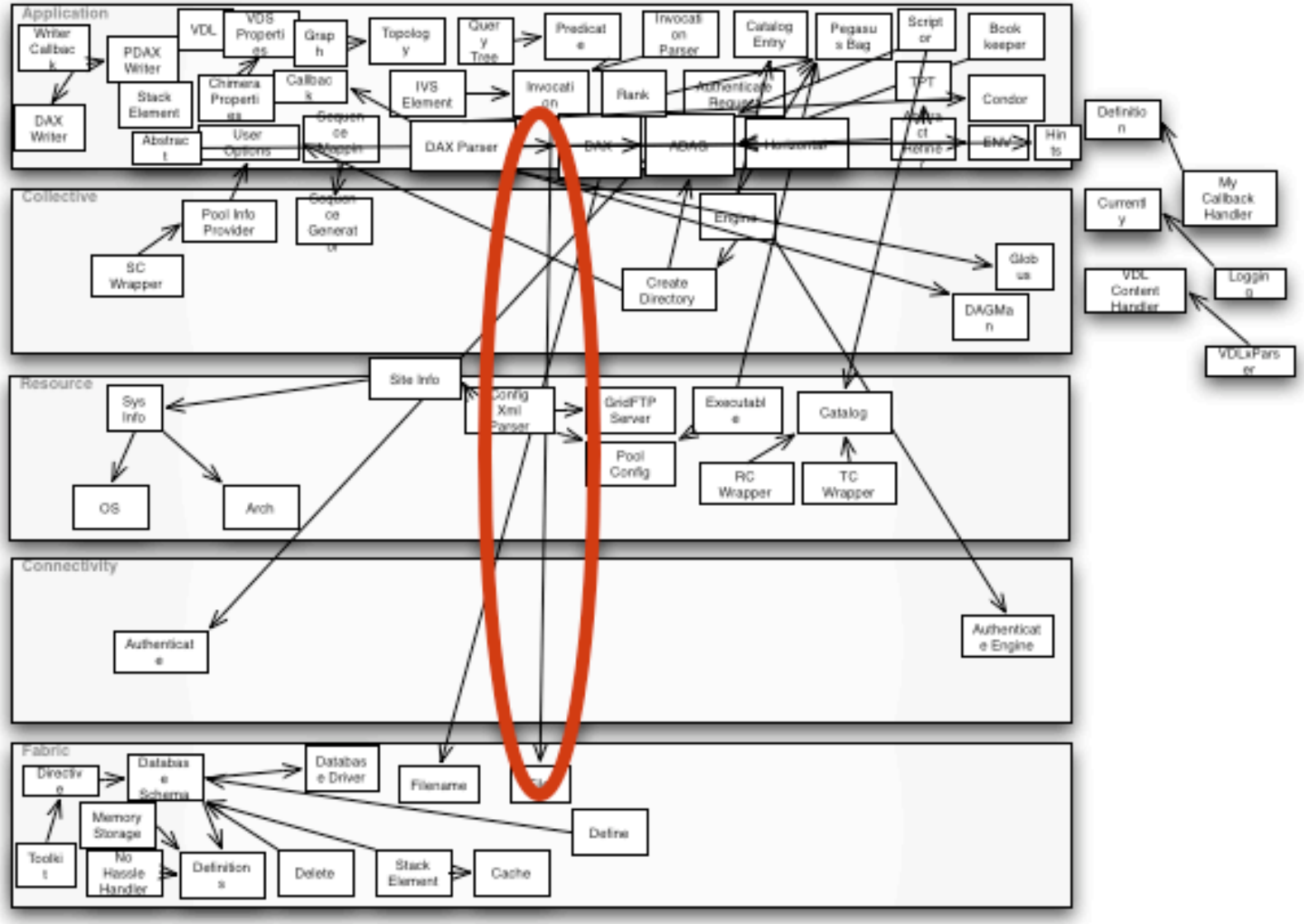
K



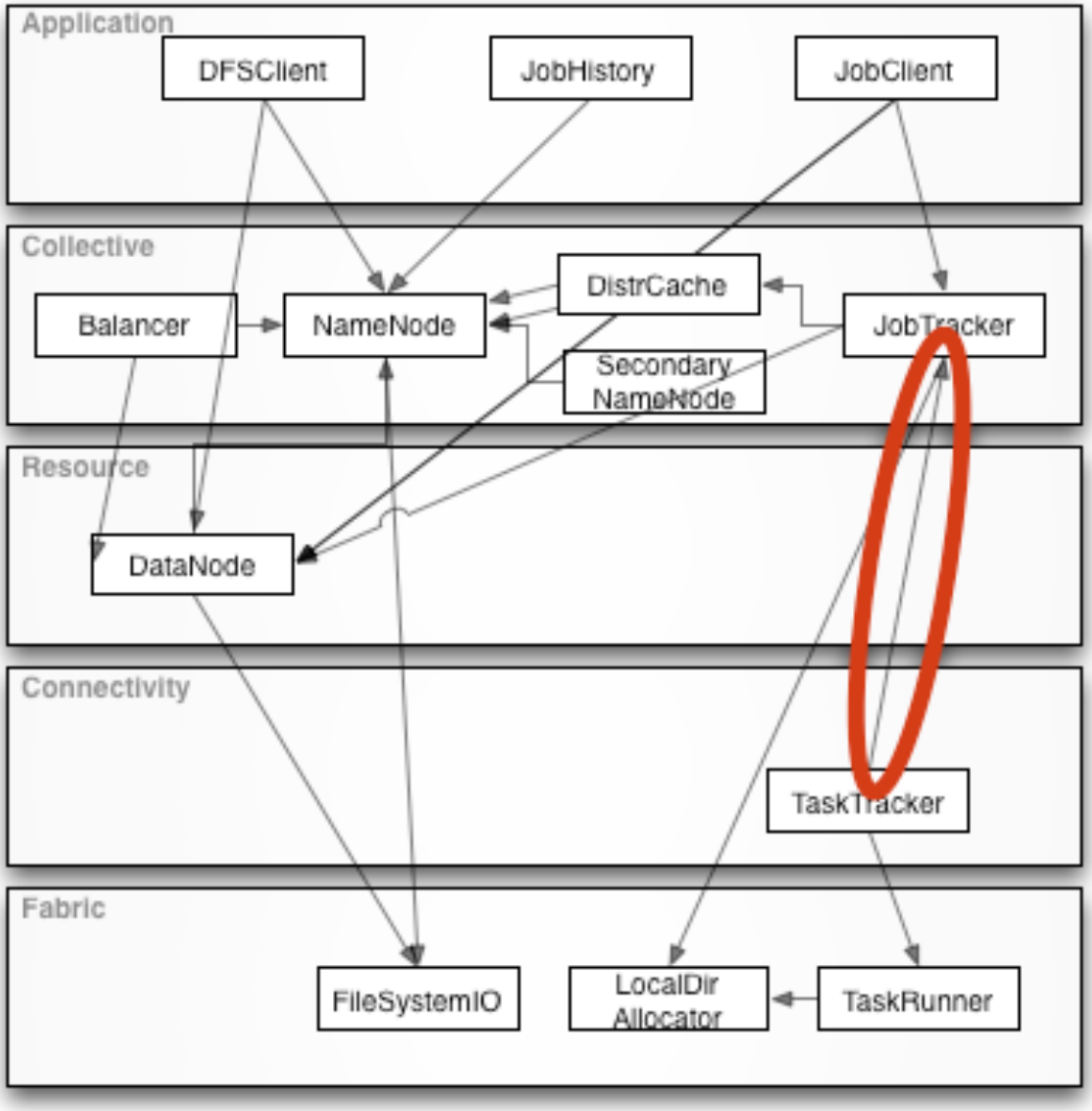
Empty Layers – Wings



Skipped Layers – Pegasus

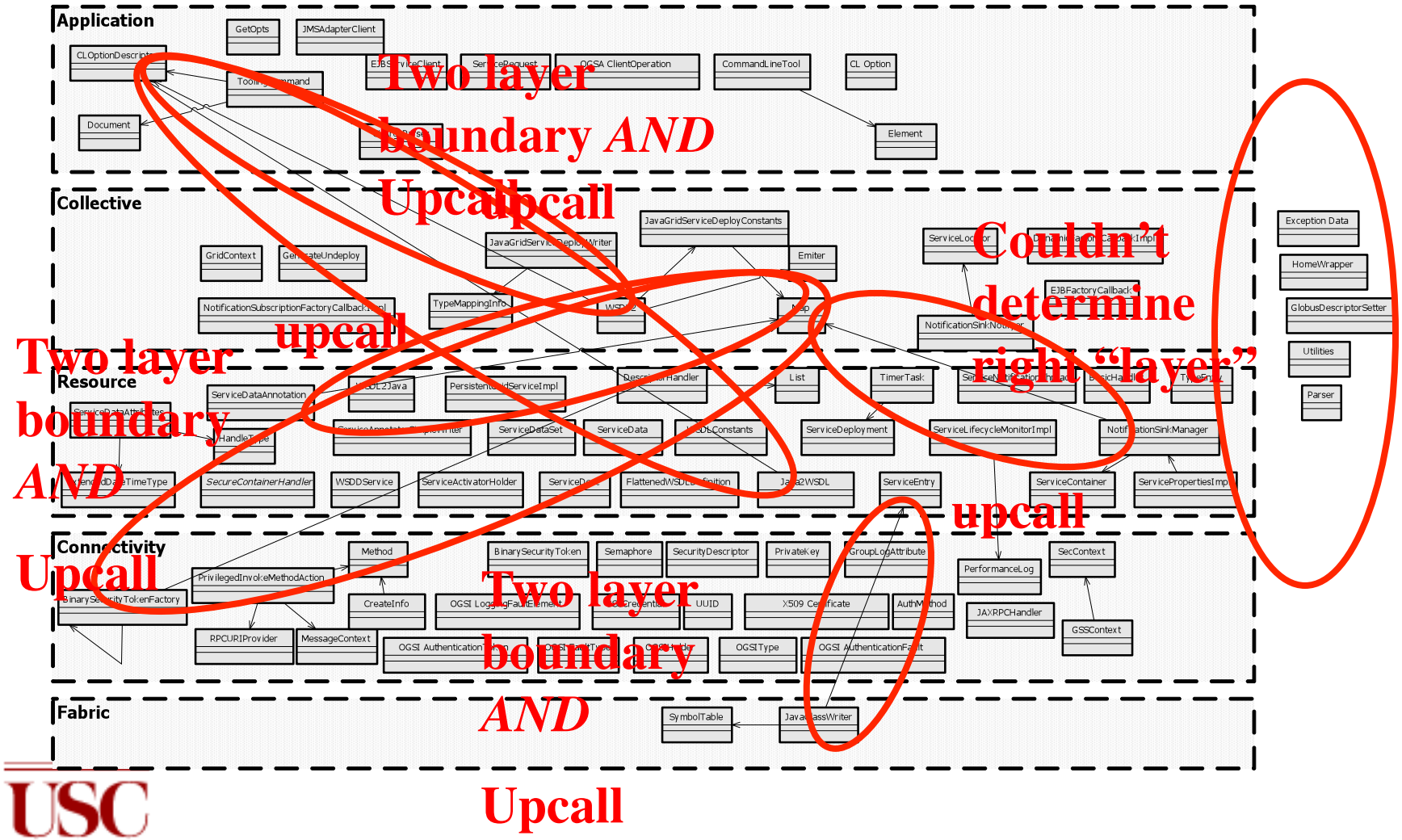


Upcalls – Hadoop



Multi-Layer Components – iRods

A Bit of Everything in Globus



Degradation Tally

Technology	UC	SL	ML	EL
Alchemi	2	2	2	0
Apache Hadoop	2	6	0	1
Apache HBase	5	7	0	0
Condor	2	0	0	2
DSpace	1	4	1	0
Ganglia	2	2	0	1
GLIDE	2	5	0	0
Globus 4.0	6	3	0	0
Grid Datafarm	14	16	0	0
Gridbus Broker	4	4	0	1
Jcgrid	4	9	0	0
OODT	3	7	0	0
Pegasus	6	6	0	0
SciFlo	1	1	0	0
iRODS	36	46	2	0
Sun Grid Engine	1	2	0	1
Unicore	4	13	0	0
Wings	6	10	0	1
Totals:	101	143	5	7

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Can We "Smell" Architectural Decay?

- A successful system is maintained over multiple years
- After a while a system becomes like sausage
- When and where do we refactor its architecture?

➢ **Architectural smell**

- A commonly made architectural design decision that negatively impacts a system's lifecycle properties
- A smell is not a bug; it doesn't break your system – but that may be the very thing that makes it dangerous

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Inspiration

- ***Refactoring: Improving the Design of Existing Code***

  by Martin Fowler

- **Code smells are implementation structures that negatively affect system lifecycle properties**
- **Defined in terms of *implementation-level* constructs**
  - Examples: long parameter list, large methods, …
- **Code smells do not address *architectural decisions***
  - They are not necessarily even correlated with architectural degradation [Macia et al. 2012]

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A Catalogue of Architectural Smells

- Brick Concern Overload
- Brick Use Overload
- Brick Dependency Cycle
- Unused Interface
- Ambiguous Interface
- Duplicate Component Functionality
- Scattered Functionality
- Component Envy
- Connector Envy
- Connector Chain
- Extraneous Adjacent Connector

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A Catalogue of Architectural Smells

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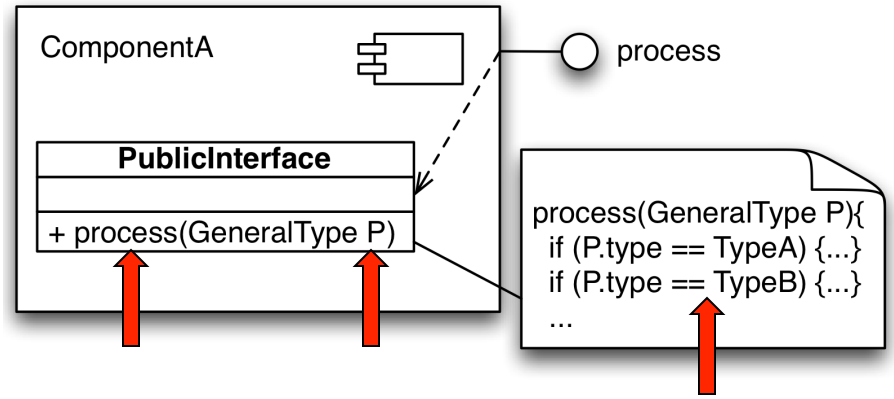
Ambiguous Interface – Description

- **Three facets of Ambiguous Interface**
  - internal dispatch to multiple services
  - offers only one public interface
  - accepts only general type



➢ **Must inspect component implementation to know its offered services or its impact**

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Ambiguous Interface – Example

Java Messaging Service

```
public void onMessage(Message msg)
  {
        String msgText;
        if (msg instanceof TextMessage) {
        ...
        } else { // If it is not a TextMessage...
        ...
        }
        if (msgText.equalsIgnoreCase("quit")) {
        ...
        }
        ...
        ...
  }
```

Ambiguous Interface – Example

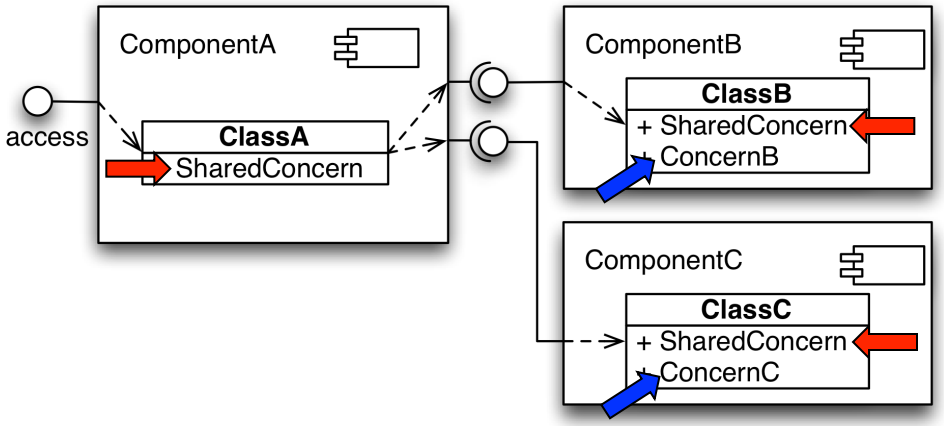
JSP servlet

```
void service(Request req)
  {
        String searchType =
          req.getParameter( “searchPref“ );
        if (searchType.equals( “zip” )) {
        ...
        } else if (searchType.equals( “type” )) {
        ...
        } else {
        ...
        }
  }
```

Scattered Functionality

- **Multiple components are responsible for realizing the same high-level concern**
- **Some of those components are responsible for orthogonal concerns**

➢ **Negatively affects reusability, understandability, testability**



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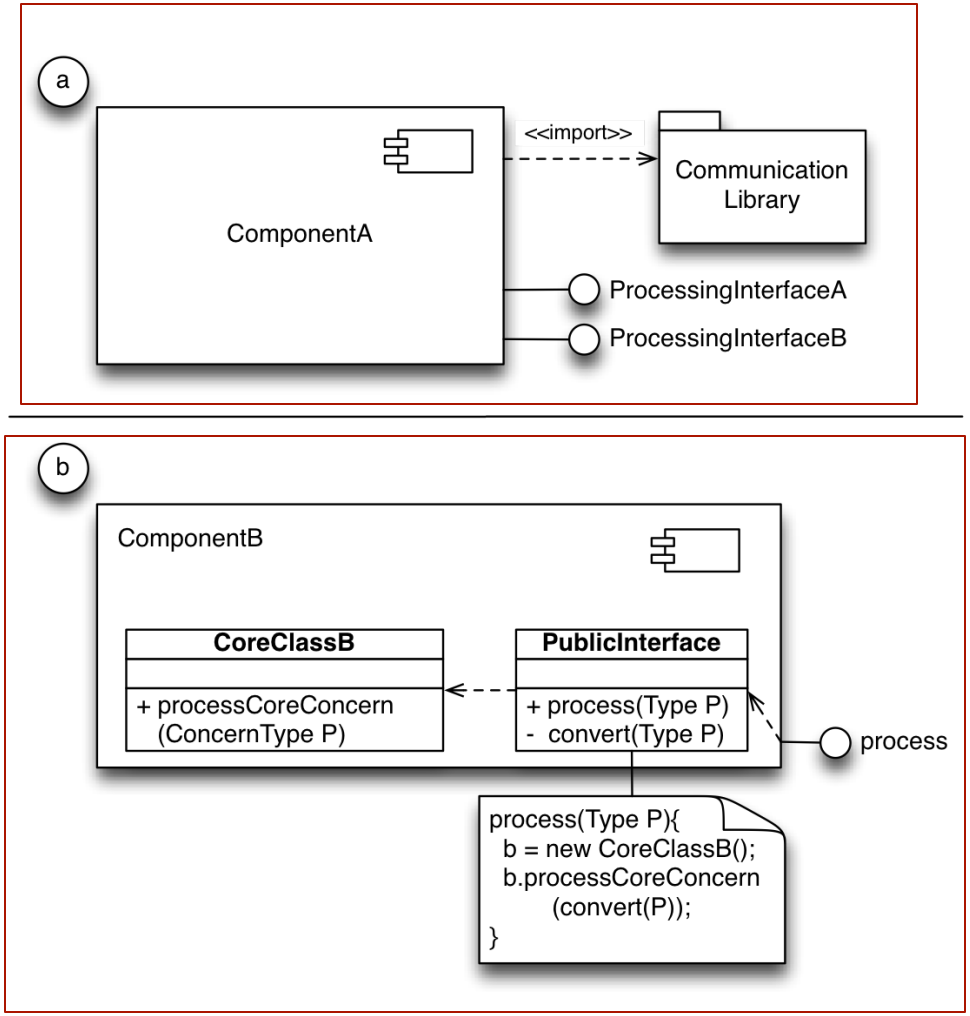
Connector Envy

- **Components provide interaction-related services**
  - Communication
  - Coordination
  - Conversion
  - Facilitation

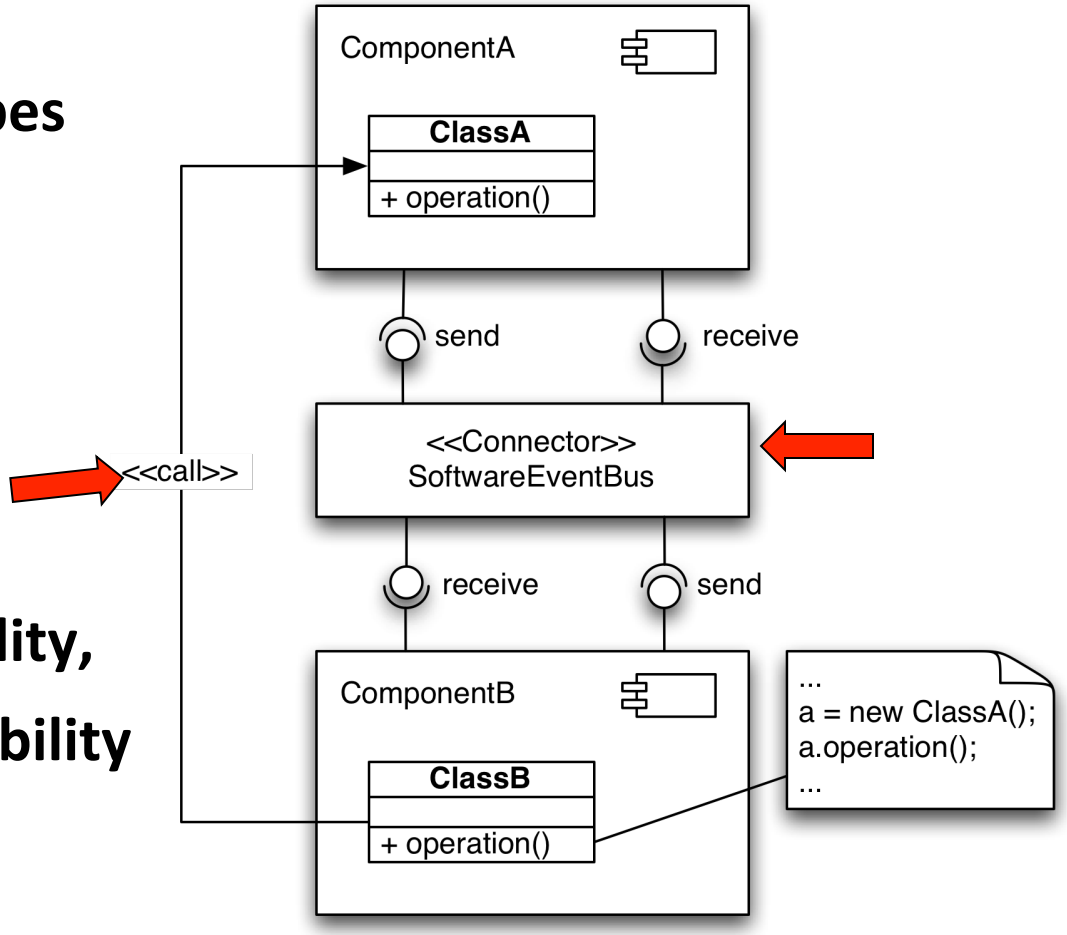
➢ **Negatively affects reusability, understandability, maintainability**



Extraneous Adjacent Connector

- **Connectors of different types link a pair of components**
- **Connectors' benefits may cancel each other**

➢ **Negatively affects reusability, understandability, adaptability**



Conclusion

- **Your architecture will degrade and get "smelly"**
  - Sometimes it starts off that way
- **Refactoring is extremely expensive**
- **You may have no choice**
- **But how do you know when, where, and how to refactor?**
- **Understanding and cataloguing smells is only the first step**
- **We are also working on**
  - Improving architectural recovery by exploiting system concerns
  - Identifying smell patterns in systems
  - Understanding their correlation with code smells

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Acknowledgments

- **Support from NSF, Bosch RTC**
- **Project participants and collaborators**
  - Yuanfang Cai, Drexel University
  - Chris Douglas, Yahoo Labs
  - Alessandro Garcia, PUC-Rio
  - **Joshua Garcia, USC**
  - Muzzammil Imam, USC
  - **Ivo Krka, USC**
  - **Isela Macia, PUC-Rio**
  - Chris Mattmann, NASA/JPL
  - Daniel Popescu, Google
  - Arndt von Staa, PUC-Rio

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