Design and Implementation of Modern Programming Languages (Seminar)

Contact

By mail:

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Timeline

- topic selection: 8.11 (Sunday after kick-off)
- paper submission: 18.12
- peer review submission: 15.01
- feedback meetings: 18.01-22.01
- camera ready: 29.01
- presentation day: **12.02**

Start Early!

- **Please let us know if you have a conflict with the presentation day**

The Seminar

- Start with several papers of a specific topic
- Understand the general area
- Find more references to complete your understanding

- Write your own paper about in that area
  - Tell a coherent story about one aspect of the topic.
  - Please present technologies, with your own words and your own examples.
    E.g. : the same running example through the paper

What you learn

- Introduce students to the core techniques of scientific work
  - Process of writing and publishing research papers
  - Review a paper
  - Give a scientific talk
- Learn an advanced topic on PL
  - Compare and evaluate existing solutions

Reviews

- A summary of the paper
  - To demonstrate that you read and understood
- Suggestions for the author, regarding both content and presentation
  - Be realistic and concrete
- A list of the major positive and negative issues
  - Honest! mainly used to grade the reviewer, not the paper

Grades

- Find the details and more info of how to write the paper on the website

- Paper 40 %
- Talk 40 %
- Reviews 20 %

- Once more. Tell a nice story. Compare things. Find advantages and limitations. Provide examples in different cases

Implementation of Programming Languages (Project)

Intro

- Goal: Implement a software artifact supporting current research.

- General scope: programming languages:
  - Extensions, code generators
  - Tools, IDEs
  - Analysis techniques
  - Performance assessments
  - Prototypes with innovative abstractions

Process

- Project details are specified by discussing with your supervisor.
  - Periodic discussions/meetings.
- Allocate one day per week to work on the project
  - Send us an email about the weekly progress.
  - Not an issue If you have no time for 1 or 2 weeks
    - Don’t abuse this.
- Presentation and delivery of the artifact and the documentation: end of the semester.

Guidelines and Suggestions

- Deliver RUNNING code
- Deliver some documentation
- Optional: final presentation / demo to discuss your work

- Team work is good!
  - Organize a team even with people you don’t know (yet)

Grades

- How much of the specification was implemented?
- The code has to run
- What is the overall quality of the code?
  - E.g. is it painful to modify/extend it?
  - Is it self-documenting?
- What is the quality of the “documentation”?

SEMINAR TOPICS

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Programming Languages for Smart Contracts

"an open, distributed ledger that can record transactions between two parties efficiently and in a verifiable and permanent way."

- How to write smart contracts?
- Need a (specification?) language…

Some examples

- "Functional Smart Contracts”
  - Chakravarty et al. 2019. Functional Blockchain Contracts.
  - Seijas and Thompson. 2018. Marlowe: Financial Contracts on Blockchain. ISoLA.
- Object-Oriented Smart Contracts
  - Coblenz. Obsidian: a safer blockchain programming language. ICSE 2017.
  - Coblenz, et al. 2019. User-Centered Programming Language Design in the Obsidian Smart Contract Language.
  - Coblenz, et al. 2019. Obsidian: Typestate and Assets for Safer Blockchain Programming
  - Schrans et al. Writing safe smart contracts in Flint. Programming 2018

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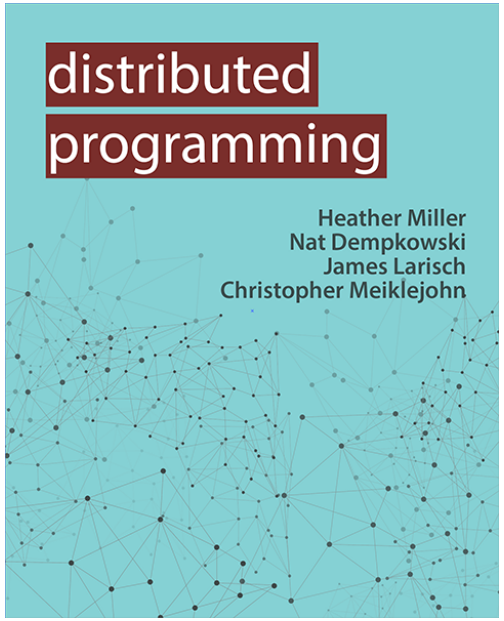
Programming models for Distributed Computing

- Very popular in the ’80, early ‘90
- A lot of ideas still influential
  - RMI, CORBA, Argus, Emerald, Akka, Linda

- Survey of the most important approaches



https://github.com/heathermiller/dist-prog-book

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Information Flow in Languages for Distributed Systems

- Distributed systems can leak private data
- Information flow type systems can prevent it
  - Attach security labels to values
  - Reject programs in case of violation

- Current Research topics
  - Interaction with distribution
  - Boundaries with databases
  - Big data
  - …

```
var l, h
if h = true
then
   l := 3
else
   l := 42
```

https://en.wikipedia.org/wiki/Information_flow_(information_theory)

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Macros and Metaprogramming

- tools and ideas on how to program interpreters and compilers
- survey on history of macro systems
- what features should modern languages support?

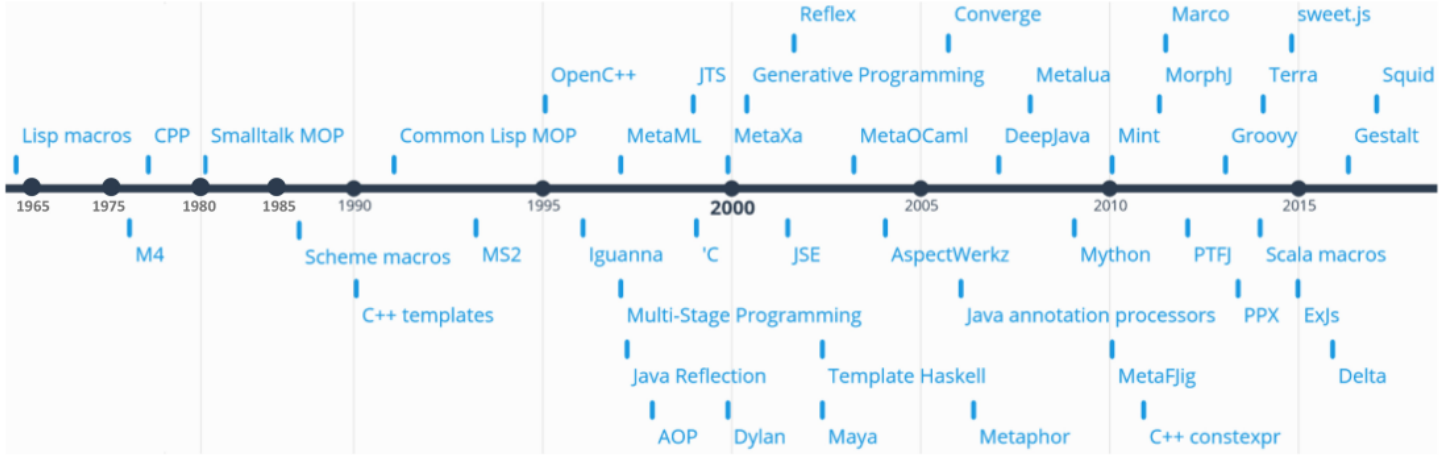
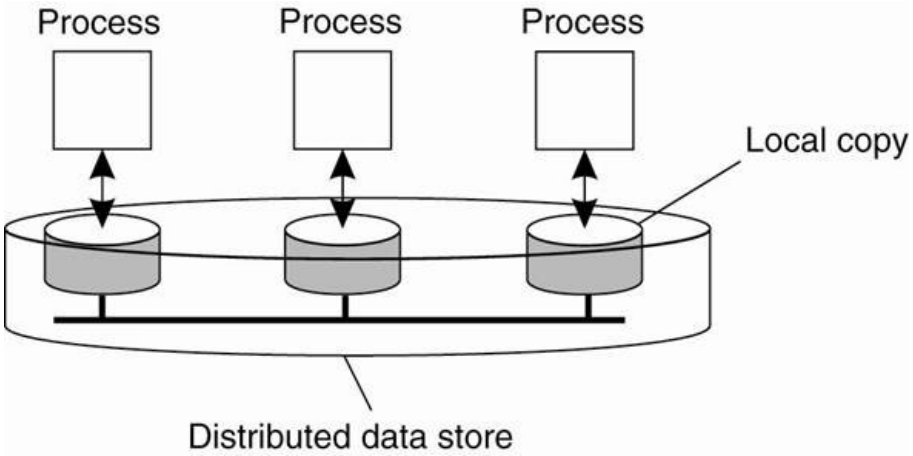


Fig. 1. Timeline of metaprogramming languages and systems; the list is not exhaustive.

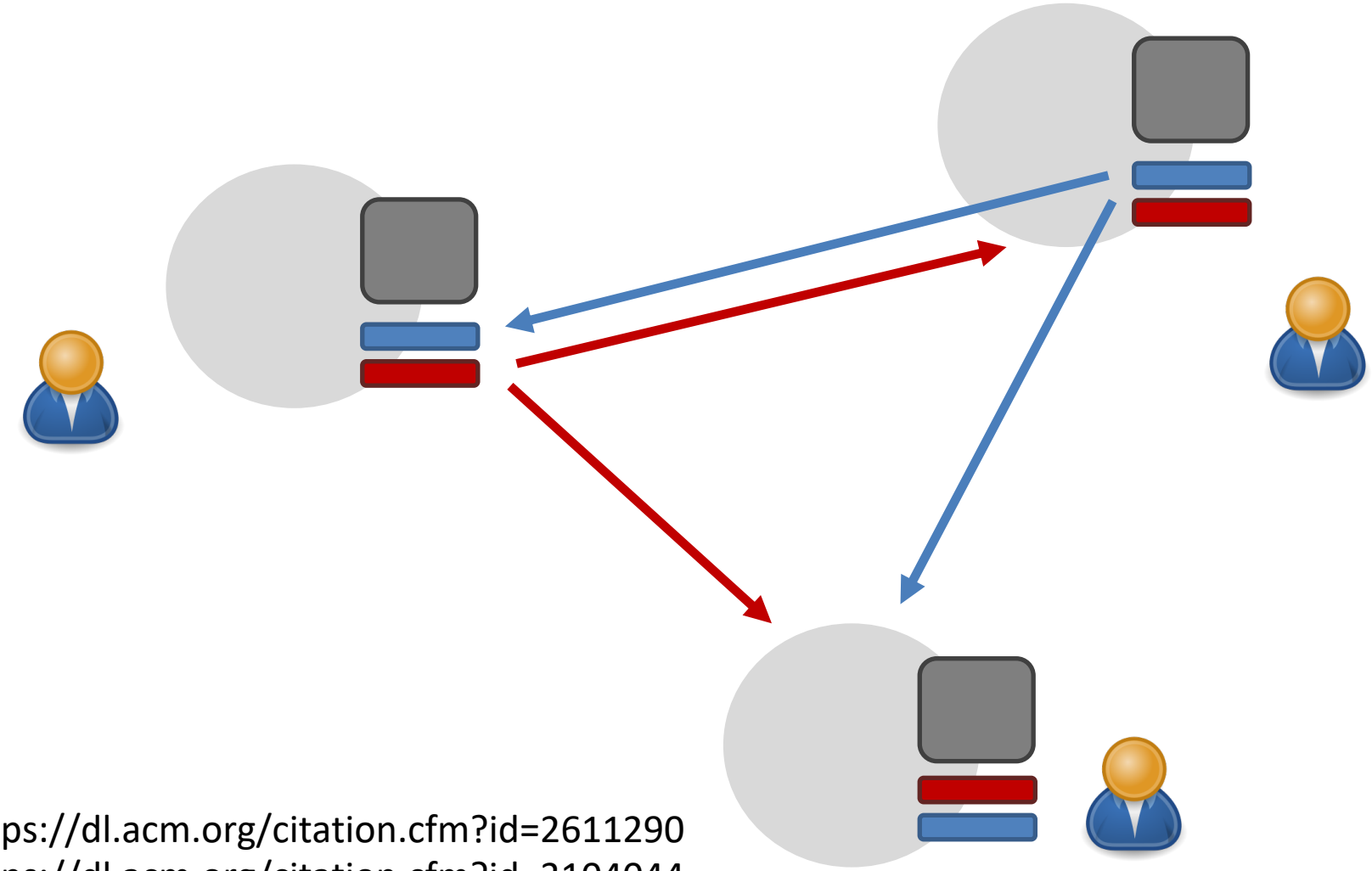
TOPICS

Consistency in PL

- Distributed systems adopt a consistency level
  - Eventual consistency
  - Causal consistency
  - …
- So far, considered only in the middleware

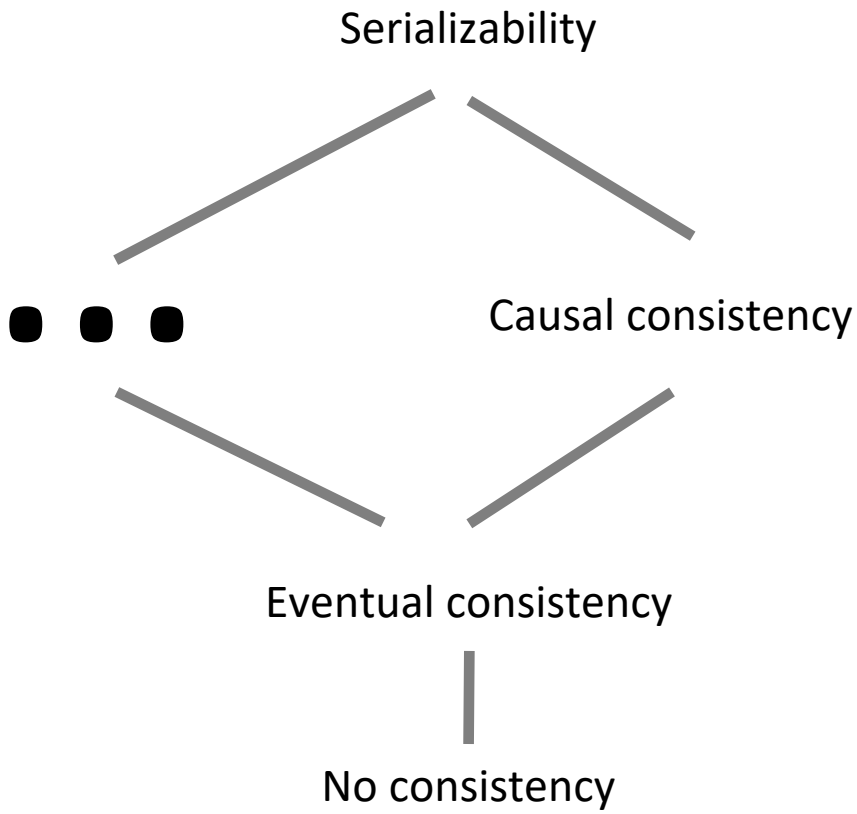


Consistency in Distributed Systems



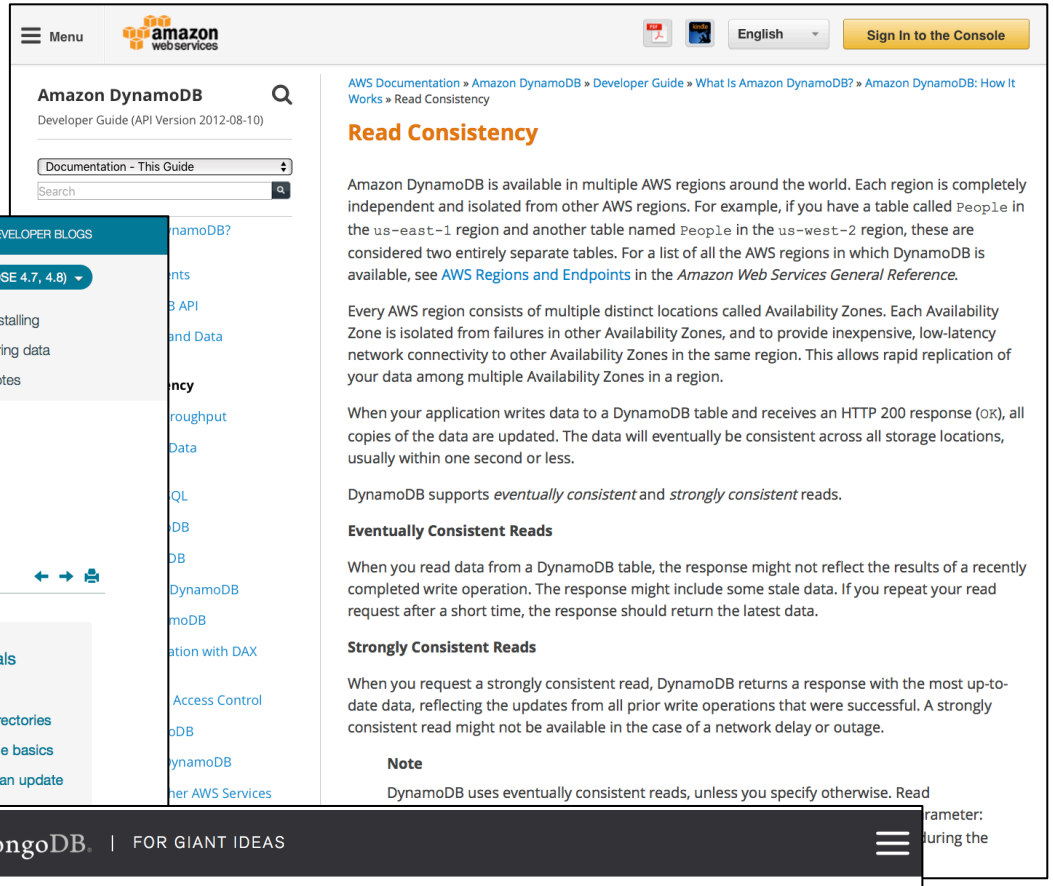
https://dl.acm.org/citation.cfm?id=2611290
https://dl.acm.org/citation.cfm?id=3104044

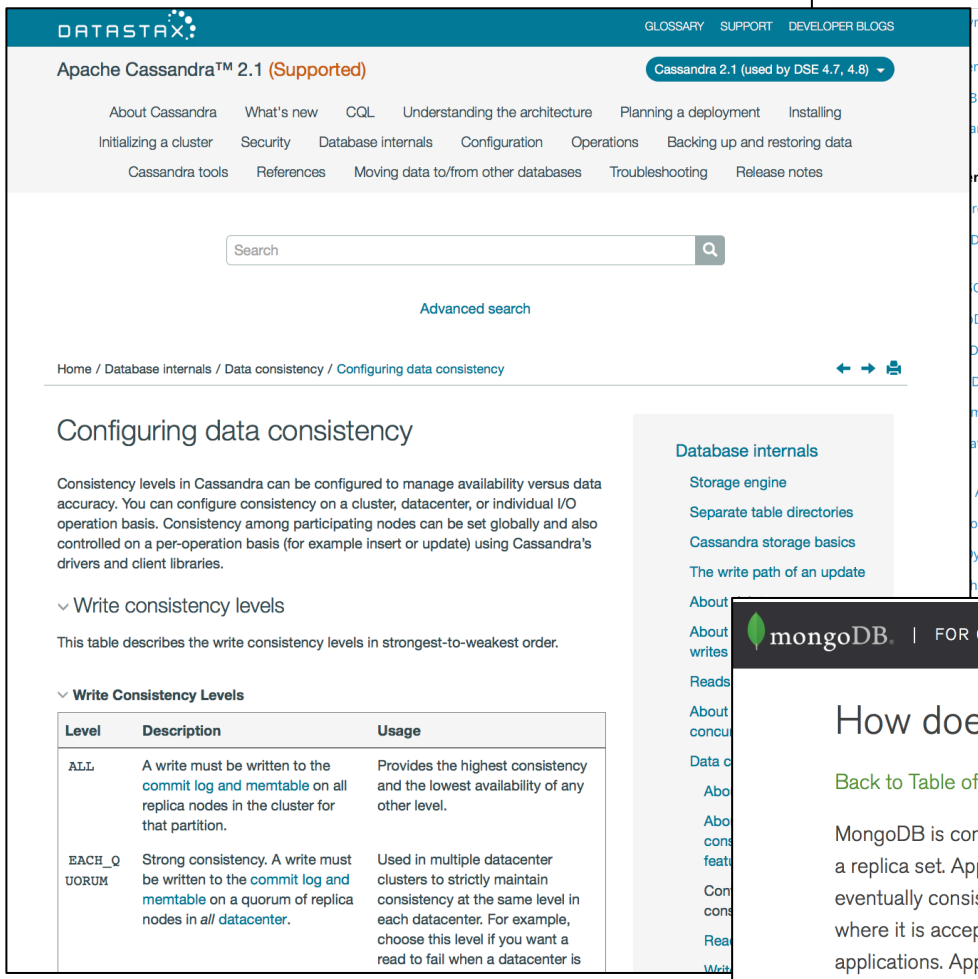
Consistency Levels form a Lattice

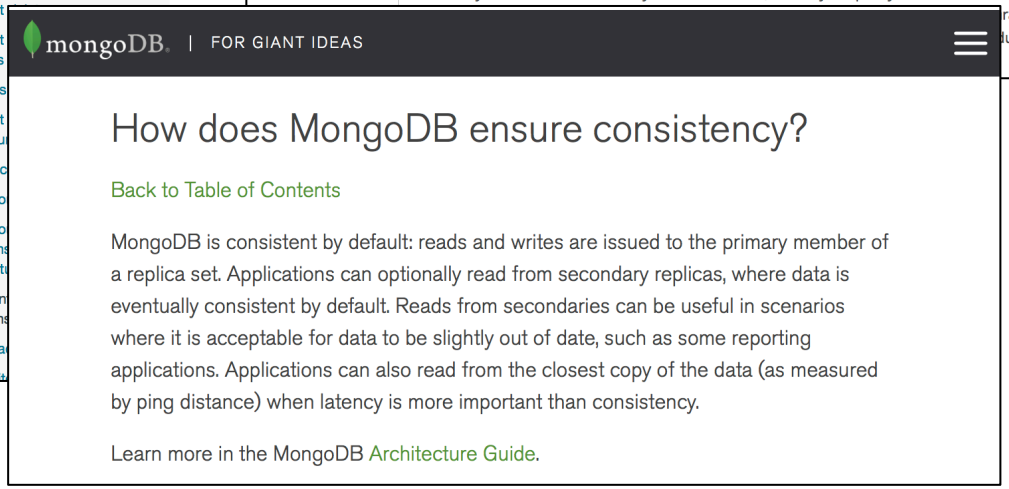


Eventual consistency
Causal consistency
Fifo consistency

....







ConSysT Programming Framework

```
class Concert {
    Date date;
    Ref<@Weak ConcertHall> hall;
    Ref<@Weak Band> band;
    Ref<@Strong Counter> soldTickets;
  …
}
```

Programming model supports
explicit consistency levels

Information flow static analysis
ensures safe mixing of consistency levels

View on GitHub

ConSysT

Tunable, safe consistency meets object-oriented programming.

https://consyst-project.github.io/

What is ConSysT?

ConSysT is an distributed object-oriented language. Objects can be replicated with different levels of consistency. The type system ensures that consistency levels are mixed safely.

Multiple consistency levels

Each replicated object comes with its own consistency level.

Safe mixing of consistencies

The static type system ensures correct mixing of consistency levels.

Object-oriented programming

Consistency is fully integrated with object-oriented abstractions.

Overview

In **ConSysT**, the main abstraction are *replicated objects* that are fully integrated into an *object-oriented* language. Replicated objects have a *consistency level* specified by the developer.

Distribution

Easily distribute your your data across your local network, datacenters or geo-replicated devices. *Replicated objects* allow to distribute and perform operations on your data. As ConSysT is implemented as a language extension to Java, you can create replicated

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Extending ConSysT

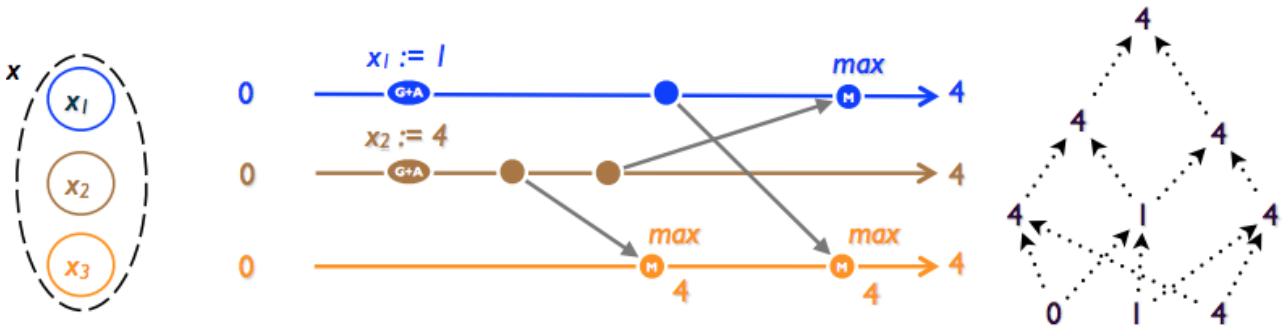
- Consistency can be associated to types e.g., High[Int]
  - Design consistency for operations, e.g., shopCheckout()
- Language support for multiple consistency levels on top of existing middleware, e.g., Cassandra

CRDTs

A data structure which can be replicated across multiple computers where replicas can be updated independently and concurrently without coordination, and where it is always mathematically possible to resolve inconsistencies

Example: collaborative editing

CRDT: Grow-only counter



Applications

- Redis: a distributed, highly available and scalable in-memory database
- Riak: a distributed NoSQL key-value data store based on CRDTs
- Facebook implements CRDTs in their Apollo low-latency "consistency at scale" database

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Delta CRDTs

- Implementation of CRDTs in Scala
- Delta replication for efficiency
- Composability of CRDTs.
  How to derive new CRDTs by composition?

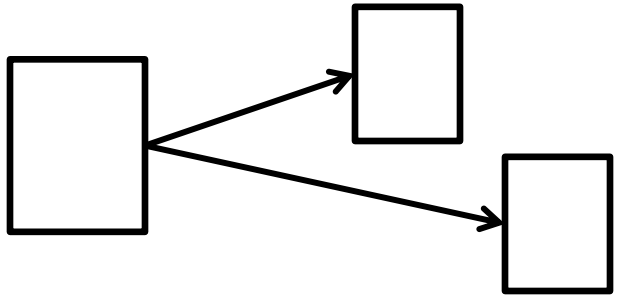
https://arxiv.org/abs/1803.02750

Tierless/Distributed Languages

Tierless Languages

- Traditional development of Web applications
  - Server side (e.g. servlet, php script, ..)
  - Client side (Javascript, …)
- Tierless languages unify the development of server-side and client-side components
  - Network communication is hidden
  - The compiler automatically generates the code for the server and for the client

https://github.com/scala-loci



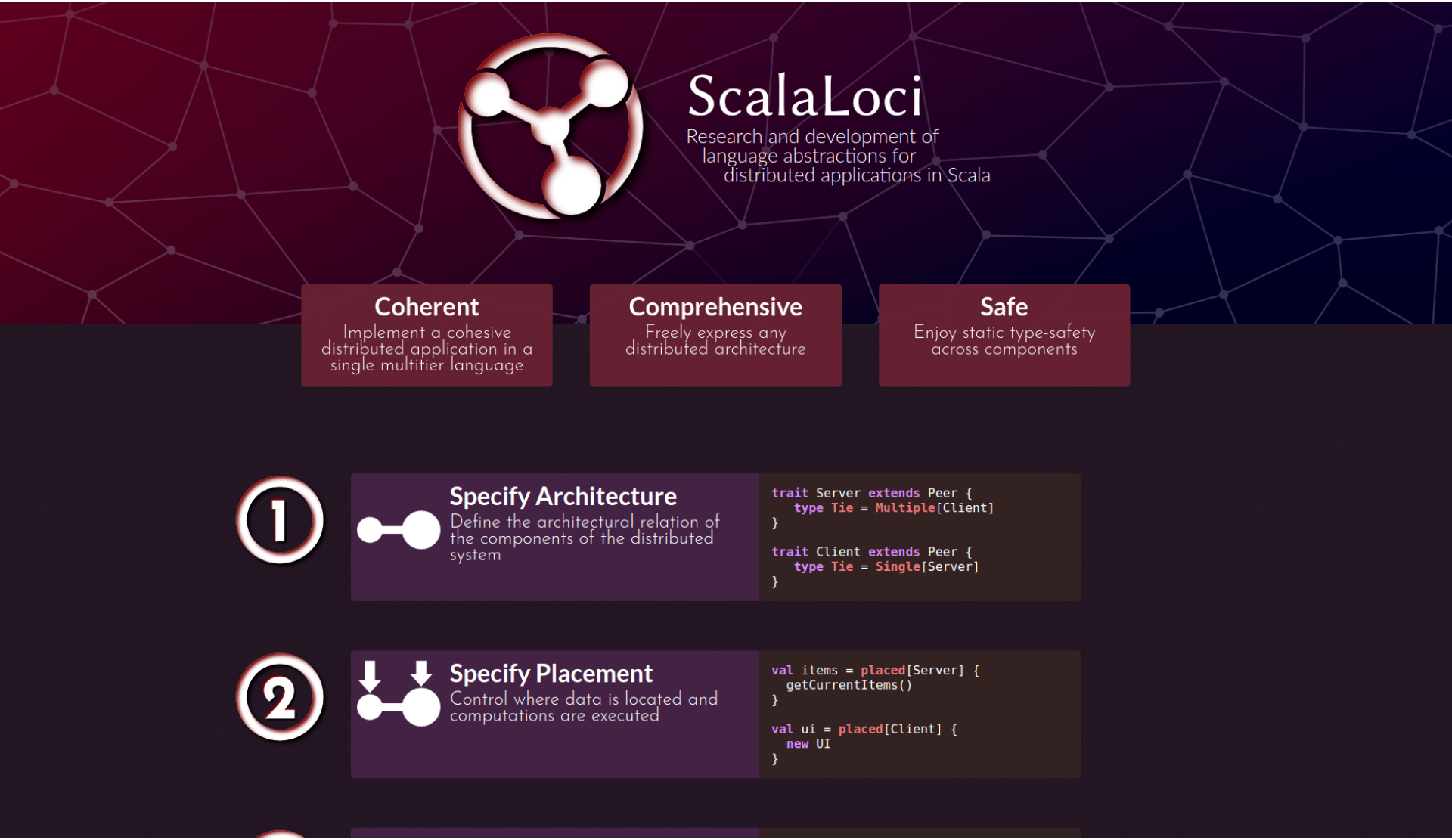
Placement Types

```
trait Registry extends Peer
trait Node extends Peer

val message: Event[String] on Registry
  = placed { getMessageStream() }
```

Peers

Placement Types



www.scala-loci.github.io

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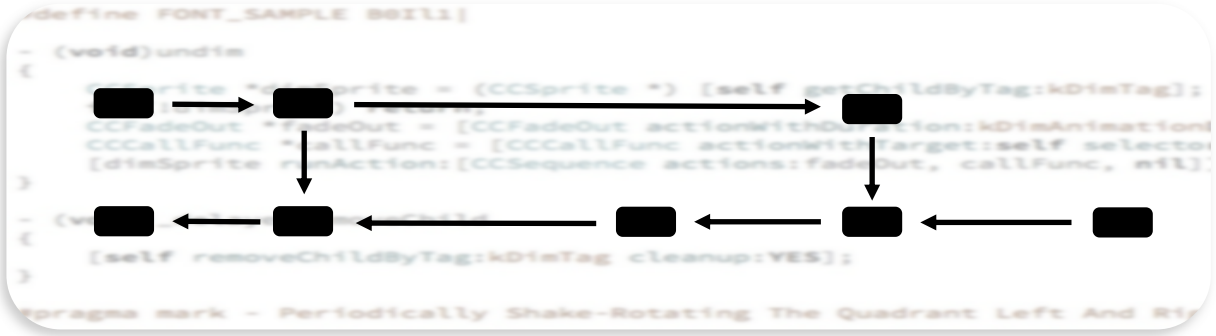
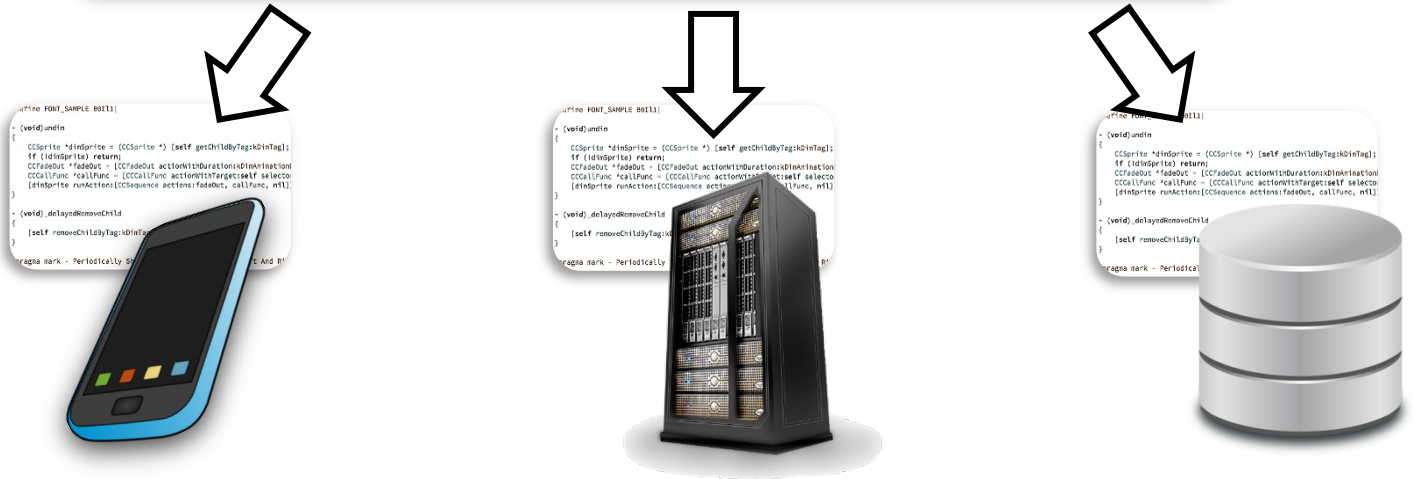
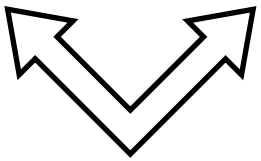
Dynamic placement







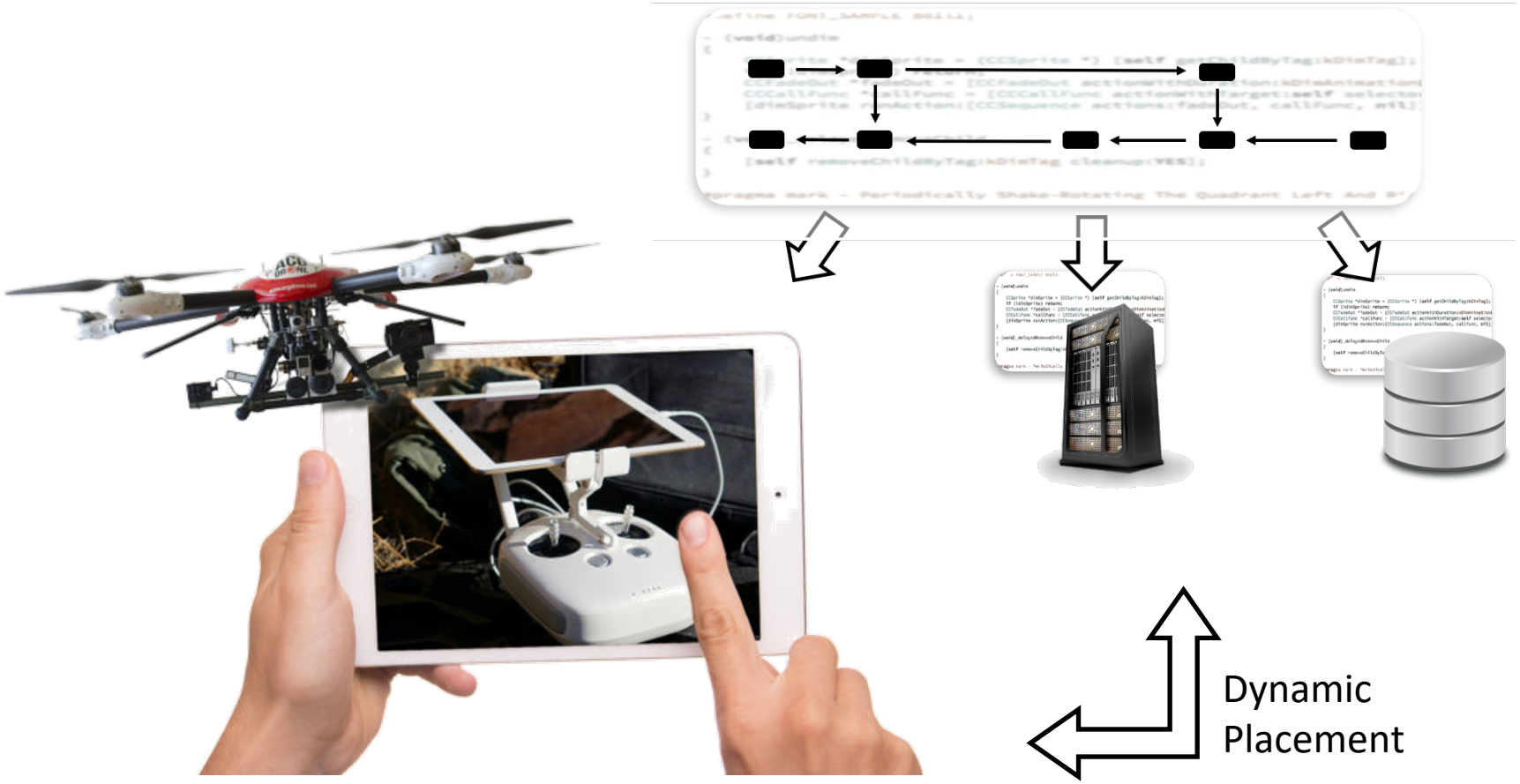
Dynamic Placement

Data streams cross Tier boundaries

Compiler splits the code

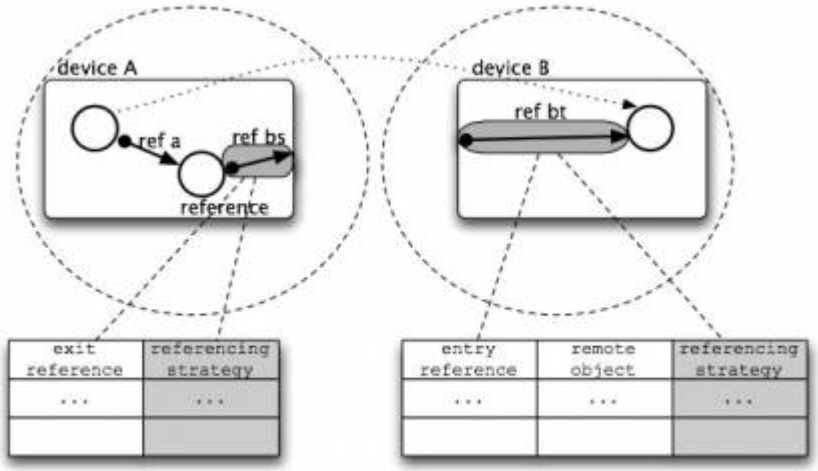
Application deployment

IoT & Edge: Drones



Distributed Garbage Collection

- Expensive in the general case!
- Use a type system to track ownership
  - The type system guarantees that there are no other refs to an object
  - The object can be deleted



https://soft.vub.ac.be/amop/research/dgc

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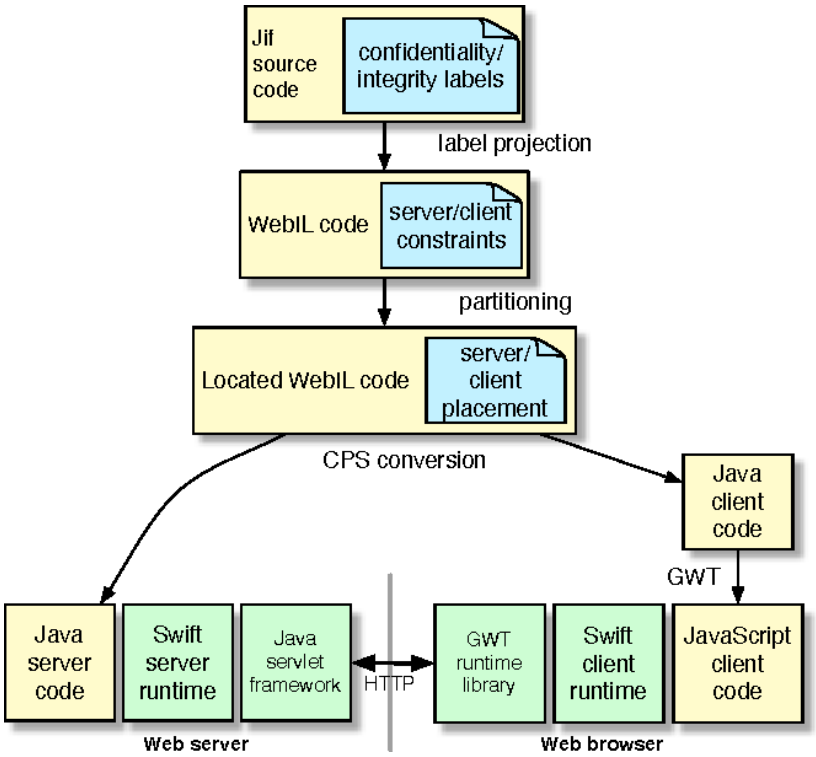
Secure Tierless Languages

- Place functionalities based on **privacy** requirements
  - Function f(x) may run on the server or on the client
  - Decide based on the privacy of x

Challenges:

- Information flow analysis
- Decision at runtime?

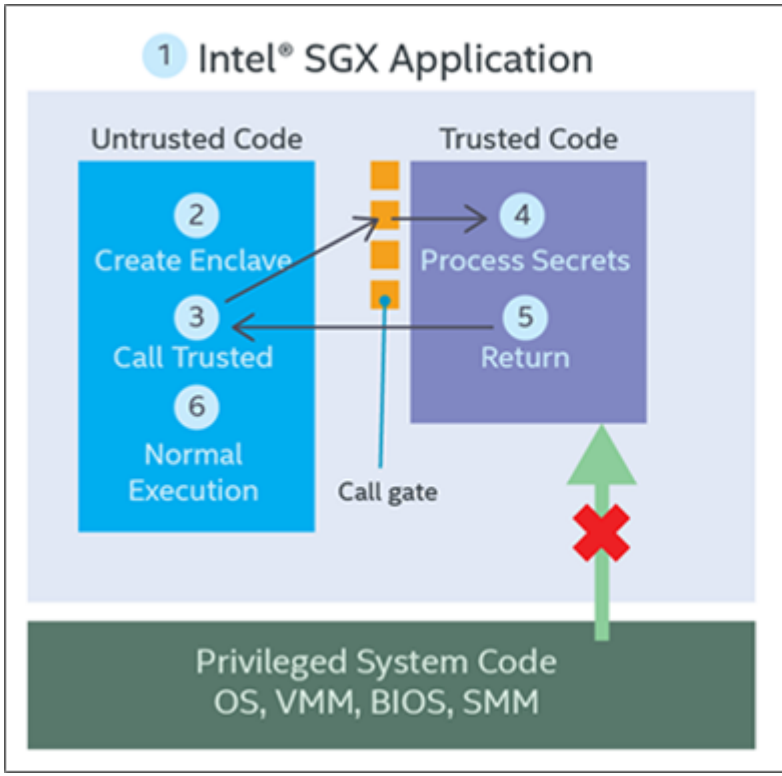


Secure Web Applications via Automatic Partitioning

Secure Tiers

- Intel Software Guard Extensions (SGX)
- Code running inside secure enclave can be seen as a separate tier

- Automate secure deployment



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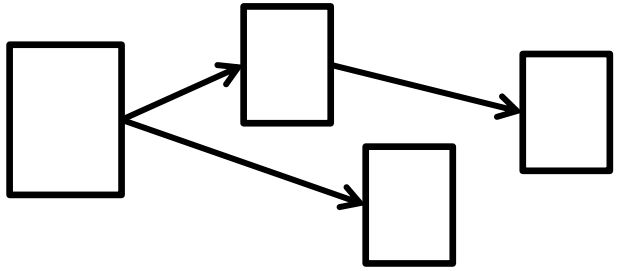
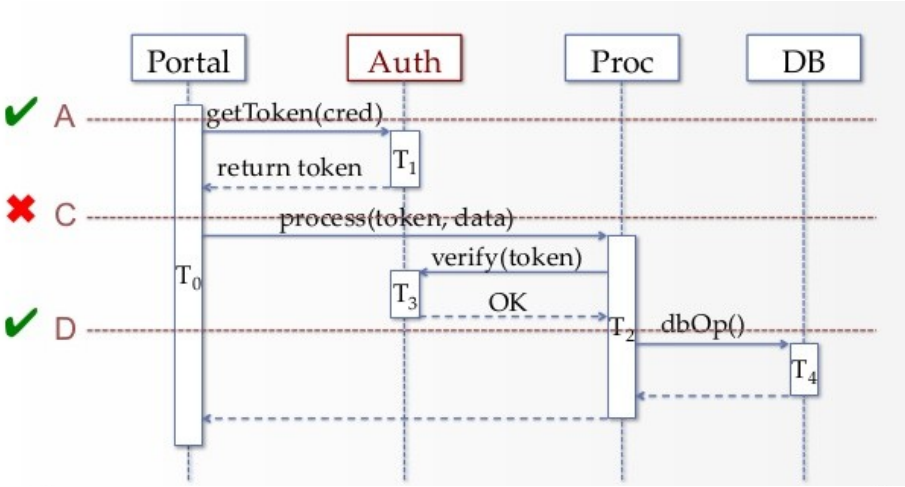
Dynamic Software Updates

- Complex component-based systems require updates without downtime



- When is an update safe?
- Develop a system for safe dynamic updates



https://dl.acm.org/citation.cfm?id=3084561

Distributed Reactive Programming

Reactive Programming

Home Manual Projects Publications Scaladoc

REScala

REScala is a Scala library for functional reactive programming on the JVM and the Web. It provides a rich API for event stream transformations and signal composition with managed consistent up-to-date state and minimal syntactic overhead. It supports concurrent and distributed programs.

Flexible	Consistent	Thread-safe
Abstractions for Events and Signals. Integrating with imperative, object-oriented, functional and any other paradigm on the JVM.	No temporary inconsistencies, no data races, no surprises. Write code which behaves as expected.	Multi-threaded applications are fully supported. Reactive abstractions can be safely accessed from any thread and they are updated in parallel.

Visit the **manual** to get started.

Project Description

Software applications react to external changes such as the input from the user and network messages. Traditionally, object-oriented software adopts the Observer pattern to implement reactivity and decouple the observers from the observables. Whereas researchers have highlighted the drawbacks of this style for a long time, alternatives struggle to be widely accepted. In particular, functional reactive programming and dataflow programming – which aim to represent time-changing values as first class abstractions – are promising, but hardly escape the functional setting. On the other hand, event-based languages directly support events but do not achieve the declarative style of more functional approaches.

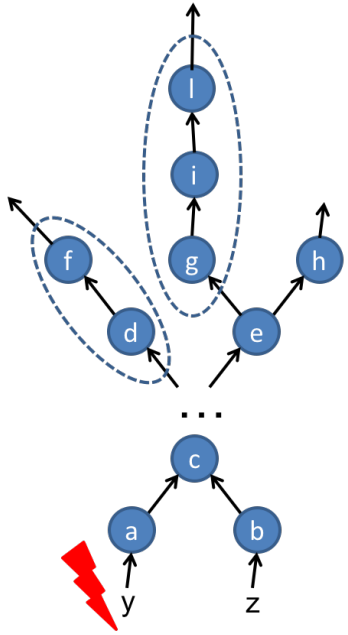
REScala is a reactive language which integrates concepts from event-based and functional-reactive programming into the object-oriented world. Rescala supports the development of reactive applications by fostering a functional and declarative style which complements the advantages of object-oriented design.

Contributors

Project lead:

- Mira Mezini
- Guido Salvaneschi

```
List<String> myList = Arrays.asList("a1", "a2", "b1", "c2", "c1");
myList.stream()
    .filter(s -> s.startsWith("c"))
    .map(String::toUpperCase)
    .sorted()
    .forEach(System.out::println);
```



www.rescala-lang.com

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IoT & Edge: Distributed Dataflow

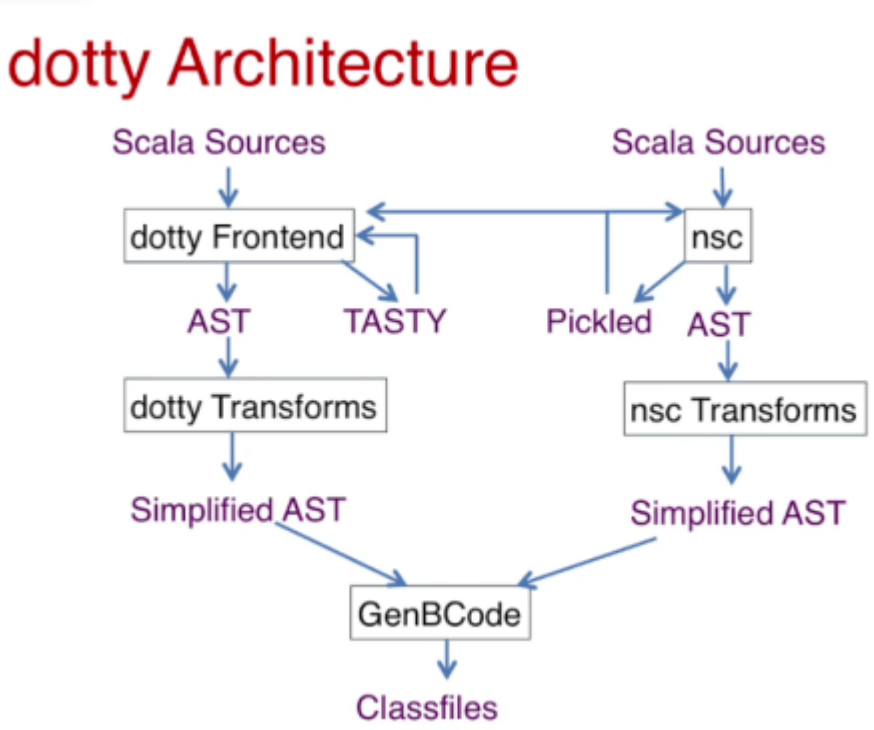
- Manage dataflow graph of many devices
- Use device specific effects for inputs & outputs
- Efficient compilation
- Failure modes? Dynamic placement? CRDTs?

Delay Tolerant Routing

- Some networks have long delays
  - Inter Planet!
  - Hand USB sticks to your friends
  - IP Datagrams on Avian Carriers (RFC 1149)
- Special routing protocols exists
- Integrate with dataflow

Staged Dataflow Graph

- dotty (new scala version) has a staged macro system
- can this be used to imlement dataflow graphs during compile time?



QUESTIONS?