Speeding up Type-specific Instrumentation for the Analysis of Complex Systems

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Dynamic Analysis

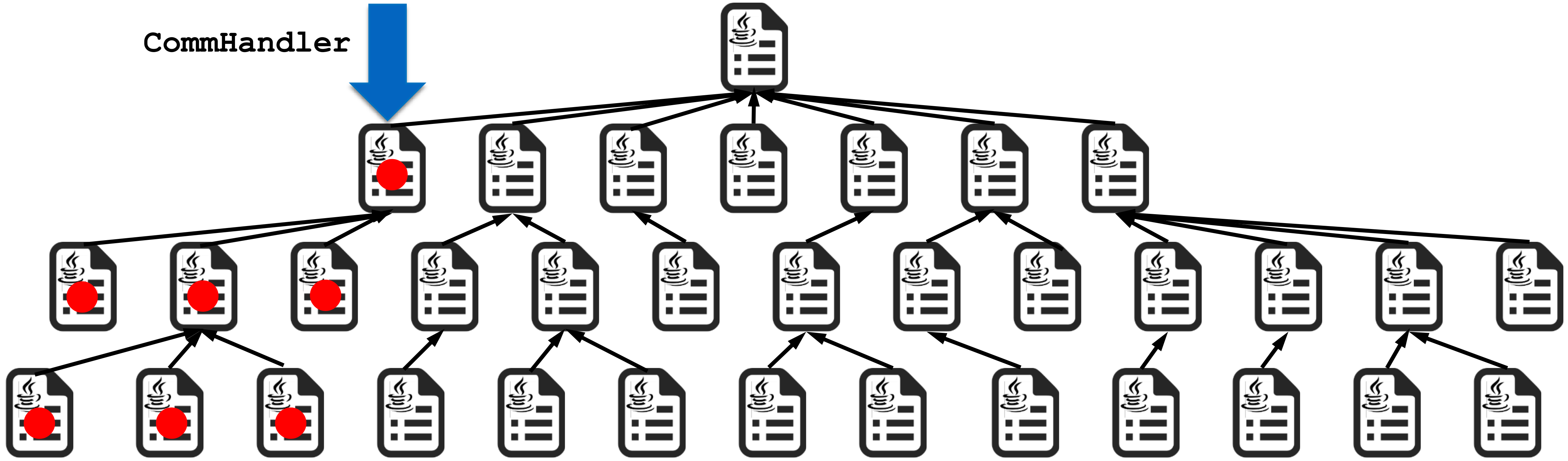
- Dynamic analysis is fundamental for complex systems
  - Enables performance analysis and improvements
- Desired dynamic analysis:
  - Efficient: limited slowdown
  - Complete: profile all relevant components

Dynamic Analysis

- Our focus: **type-specific** dynamic analyses **on the JVM**
  - Often rely on bytecode instrumentation
  - Instrumentation may rely on **reflective supertype information (RSI)**
    - Information on all direct and indirect supertypes
    - Provided by methods of `java.lang.Class`
      - `public Class<? super T> getSuperclass()`
      - `public Class<?>[] getInterfaces()`
      - Recursively applied
- RSI may not be available, resulting in inefficient analyses

RSI during Instrumentation

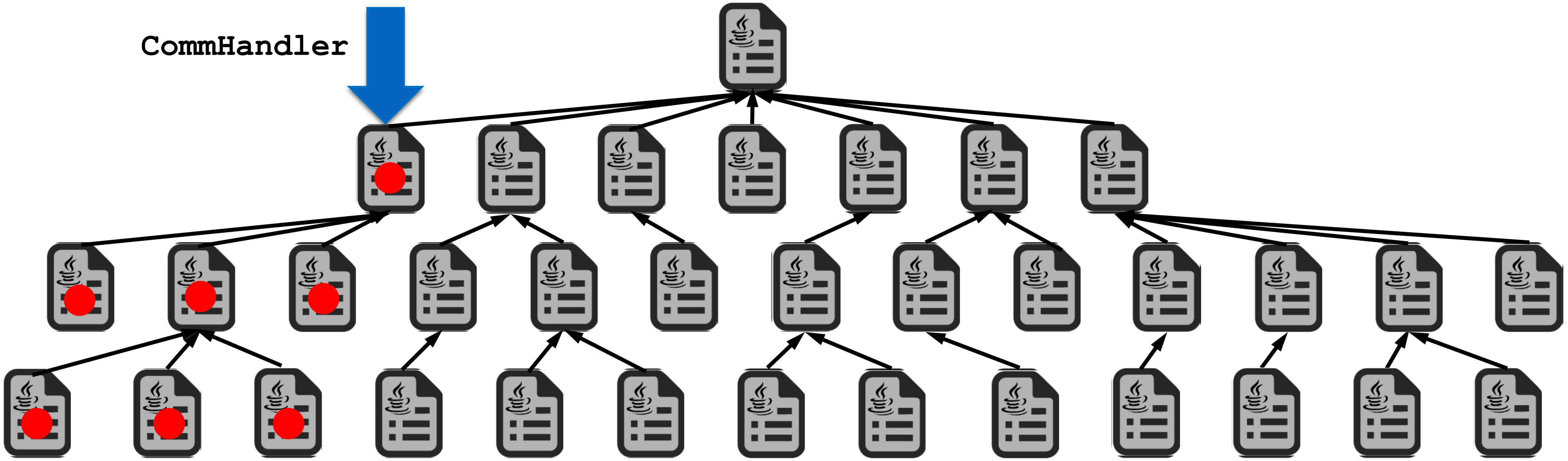
- Example: type-specific analysis targeting communication handlers



- **Without** RSI:

RSI during Instrumentation

- Example: type-specific analysis targeting communication handlers

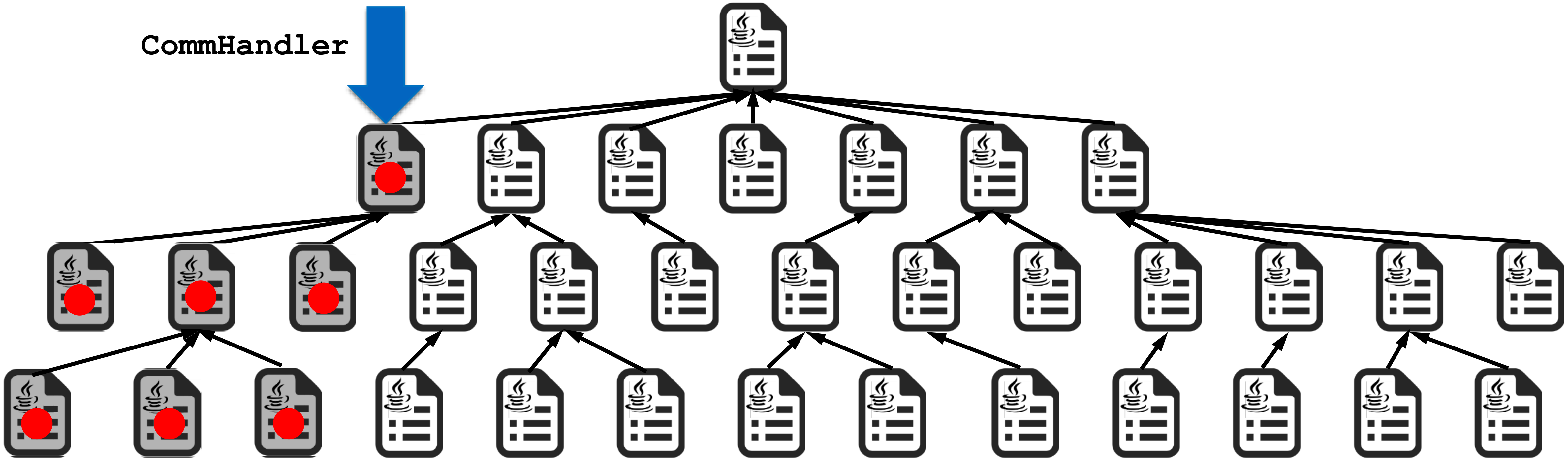


- Without RSI:
  - Many classes instrumented
  - Increased overhead

```
if (this instanceof CommHandler){
    // Do something
}
```

RSI during Instrumentation

- Example: type-specific analysis targeting communication handlers

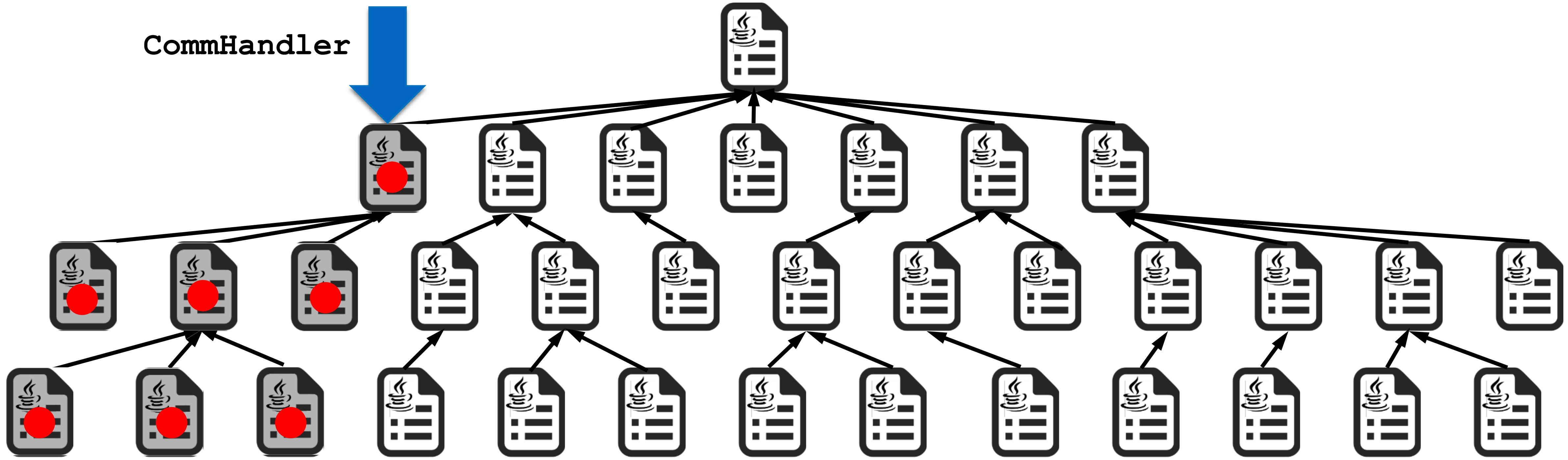


- With RSI:
  - Less classes instrumented
  - Less overhead

```
~~if (this instanceof CommHandler){~~
    // Do something
~~}~~
```

RSI during Instrumentation

- Example: type-specific analysis targeting communication handlers



- With RSI:
  - Less classes instrumented
  - Less overhead

Availability of RSI
vs
Full code coverage

Efficiency
vs
Completeness

RSI during Instrumentation

Instrumentation	Complete RSI available?	Full code coverage?
Compile-time (e.g., AspectJ [1] compile-time weaver)	✗	✗
Load-time in-process (e.g., AspectJ [1] load-time weaver)	✓	✗
Load-time out-of-process (e.g., DiSL [2])	✗	✓
Our approach (DiSL [2])	✓	✓

[1] Kiczales et al. *An overview of AspectJ*. ECOOP'01.

[2] Marek et al. DiSL: *A Domain-specific Language for Bytecode Instrumentation*. AOSD'12.

RSI during Instrumentation

Instrumentation	Complete RSI available?	Full code coverage?	Classloader namespaces?
Compile-time (e.g., AspectJ [1] compile-time weaver)	✗	✗	✗
Load-time in-process (e.g., AspectJ [1] load-time weaver)	✓	✗	✗
Load-time out-of-process (e.g., DiSL [2])	✗	✓	✗
Our approach (DiSL [2])	✓	✓	✓

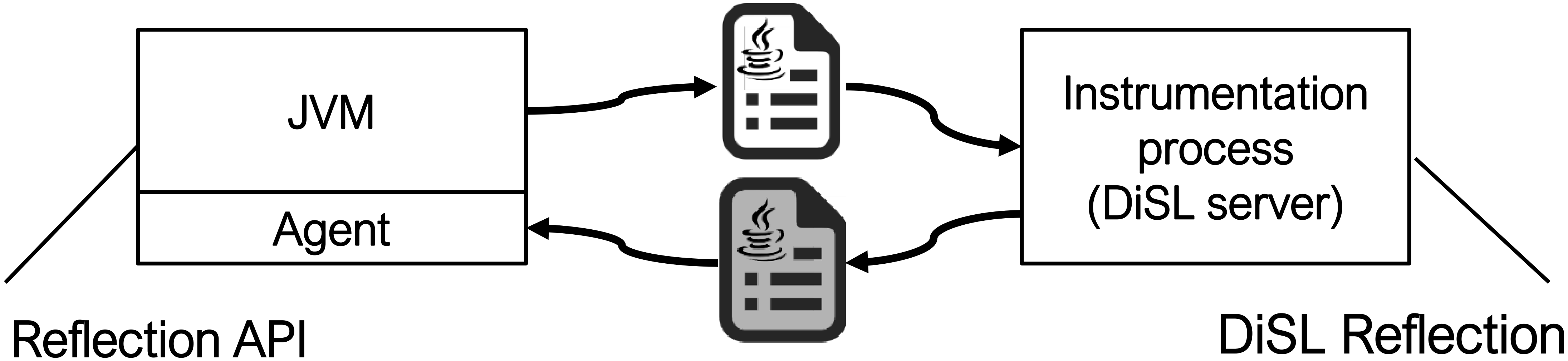
- Challenges:
  - Dynamic class loading
  - Classloader namespaces

Contribution

- We present an extension of DiSL [2] that **accurately reifies complete RSI** in a **separate instrumentation process**
  - Reification of classloader namespaces
  - Complete RSI available upon instrumentation of any class
  - Works with full code coverage

[2] Marek et al. DiSL: *A Domain-specific Language for Bytecode Instrumentation*. AOSD’12.

DiSL Reflection API



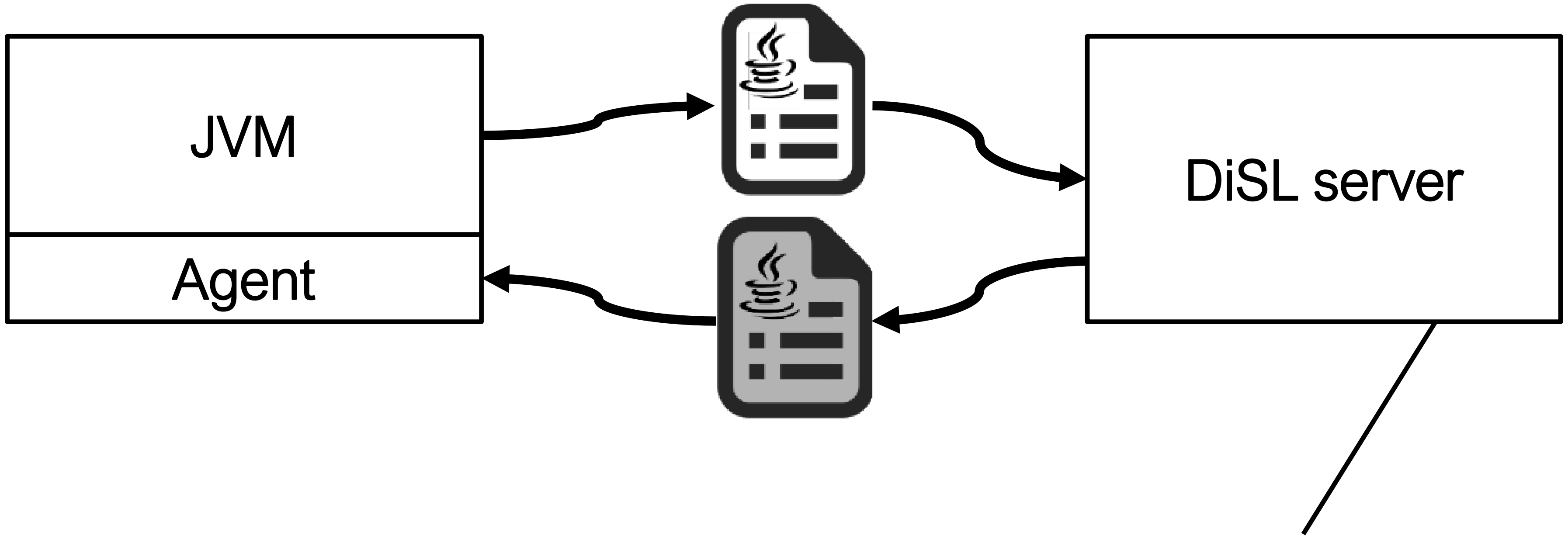
Java Reflection API
`Class, Classloader`

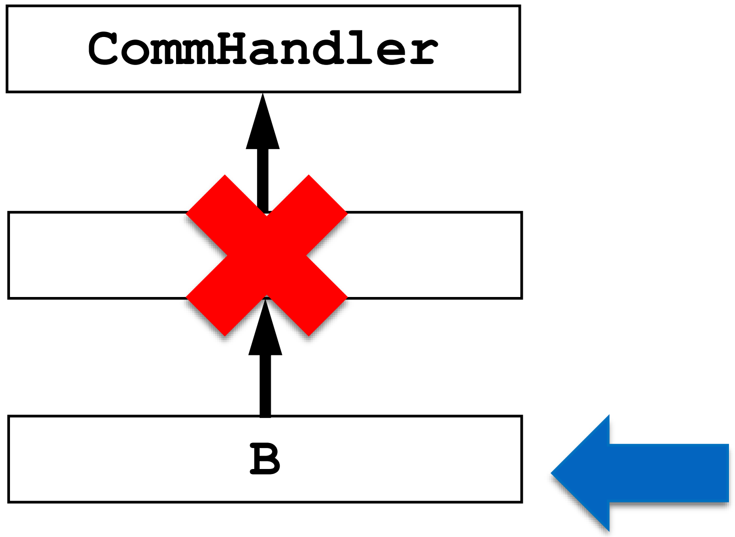
DiSL Reflection API
`DiSLClass, DiSLClassloader`

```
public interface DiSLClassLoader {
    long getID();
    DiSLClass forName(String fullyQualifiedClassName);
    boolean isBootstrapLoader();
    boolean isApplicationLoader();
    ...
}

public interface DiSLClass {
    String getName();
    DiSLClassLoader getClassLoader();
    DiSLClass getSuperclass();
    Stream<DiSLClass> getInterfaces();
    Stream<DiSLClass> getSupertypes();    // All direct and indirect supertypes
    ...
}
```

Forced Loading of Supertypes



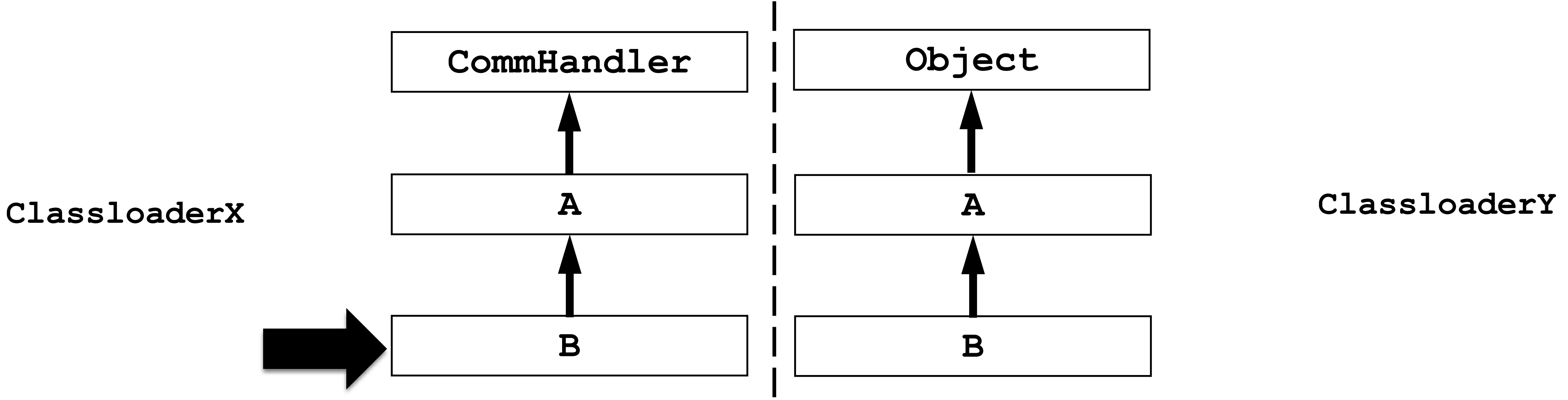


```
public interface DiSLClass {
    String getName();
    DiSLClassLoader getClassLoader();
    DiSLClass getSuperclass();
    Stream<DiSLClass> getInterfaces();
    Stream<DiSLClass> getSupertypes();
    ...
}
```

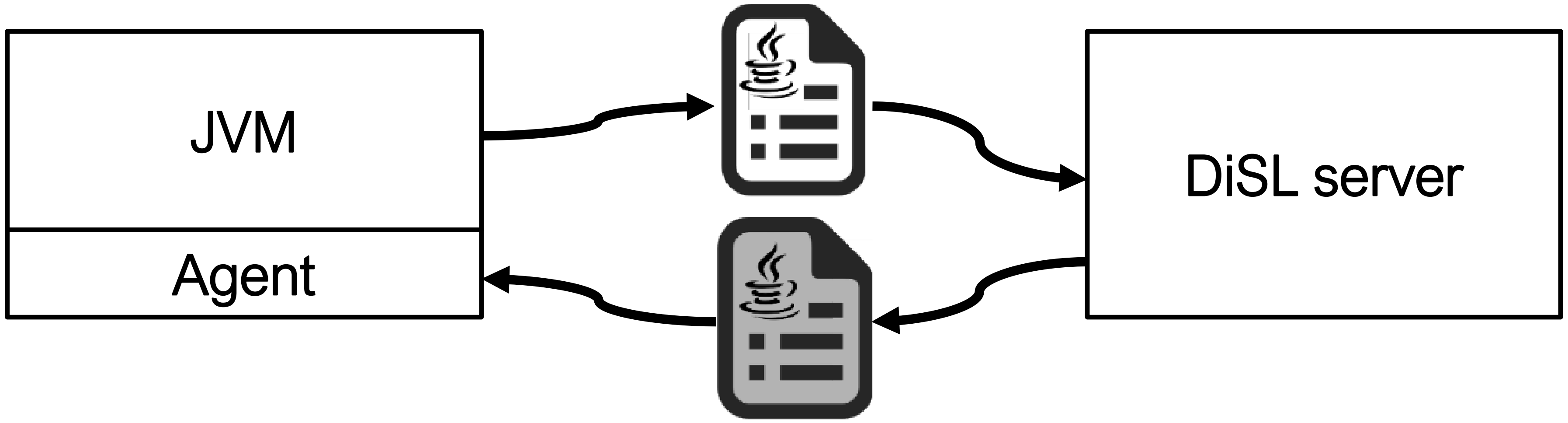
- JVM may load subtypes before supertypes

- Solution: force loading of supertypes

Classloader Namespaces



`<A, ClassloaderX>`
`<B, ClassloaderX>`



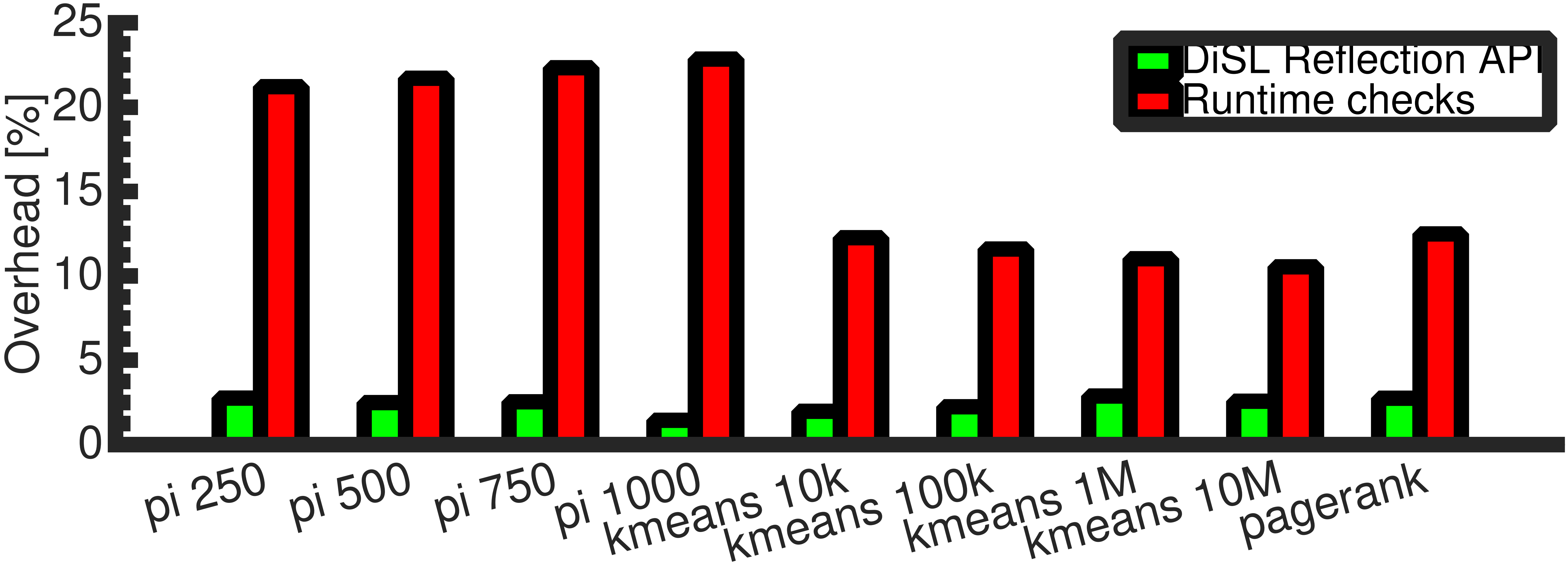
Evaluation

- Task profiling on Apache Spark [3] with *tgp* [4]
- Target workloads:
  - *pi*
  - *kmeans*
  - *pagerank*
- Comparison between:
  - DiSL without Reflection API
  - DiSL with Reflection API

[3] Zaharia et al. *Resilient Distributed Datasets: A Fault-tolerant Abstraction for In-memory Cluster Computing*. NSDI'12.

[4] Rosales et al. *tgp: a Task-Granularity Profiler for the Java Virtual Machine.* APSEC'17.

Evaluation



- High overhead without DiSL Reflection API
  - 10.5%~22.8%

- Reduced overhead with DiSL Reflection API
  - 1.4%~2.9%
  - Max difference: 21.4%

Conclusions

- Extension of DiSL that reifies RSI in a separate instrumentation process
  - Instrumentation process aware of classloader namespaces
  - Accurate and complete RSI available for each loaded class
  - Reconciles complete RSI and full code coverage
- Significant overhead reductions
  in type-specific instrumentations

Thank you for the attention

- DiSL: **`https://disl.ow2.org`**
- Andrea Rosà

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  `http://www.inf.usi.ch/phd/rosaa`