# Measuring code coverage

Uncovering the Atlassian Clover engine

# About me

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- Support Engineer and Software Developer at Spartez (since 2012)
- Senior Software Engineer at Lufthansa Systems (2004-2012)

- Technical University of Gdańsk, computer science
- Java, C/C++

- developer of the Atlassian Clover product


# Agenda

*A bit of theory ...*

- What a code coverage is not? Why to use it?
- Collecting coverage data
- Code coverage metrics

*Dive into the code...*

- Parsing Java
- Parsing Groovy

*Harness the runtime ...*

- Clover's coverage recorders
- Multi-threaded application
- Multi-threaded tests
- Multiple JVMs

# What a code coverage is NOT?

- it's not a silver bullet – it's just a metric
- it's not a „positive” metric
  - → it does not measure how your code is good
  - → it does not tell if your tests are correct
  - → it tells how much crap do you have
- it's not a „must have”
  - → follow the "80-20" rule

# Why to use code coverage?

- to identify risky code
  - *code coverage && code metrics && test failure history*
- to assist in development
  - *coverage highlihting in text editor*
  - *code reviews*
- to speed-up test execution
  - *selecting subset of tests*
  - *fail-fast approach*

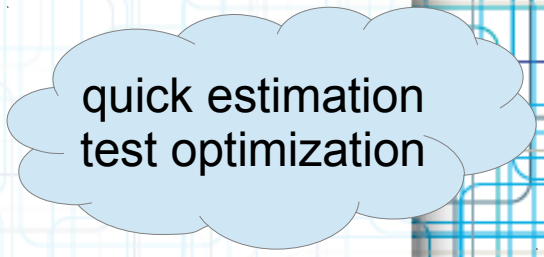
# Collecting coverage data

| Feature | JVMTI | Bytecode instr. | Source instr. |
|---|---|---|---|
| Method coverage | yes | yes | yes |
| Statement coverage | line only | indirectly | yes |
| Branch coverage | indirectly | indirectly | yes |
| Works without source | yes | yes | no |
| Requires separate build | no | no | yes |
| Works without specialized runtime | no | no | yes |
| Gathers source metrics | no | no | yes |
| Compilation time | no impact | variable | variable |
| Runtime performance | high impact | variable | variable |
| Container friendly | no | no | yes |

# Method coverage

measures whether a method was entered at all during execution

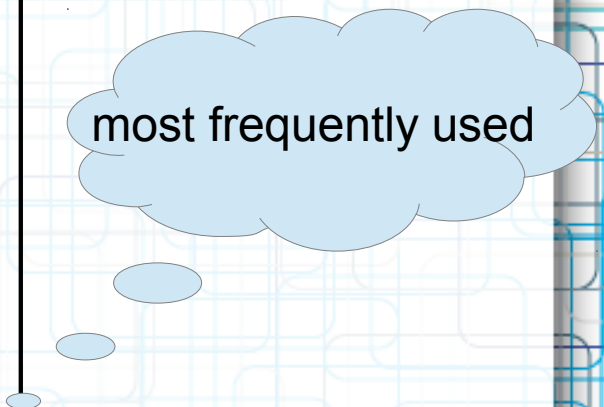
```
class MethodCoverage {

  static String foo(boolean b, int i) {
    if (b) {
       return "true";
    }
    if (i > 0) {
       return "positive";
    } else {
       return "negative or zero";
    }
  }

  public static void main() {
    foo(true, 0);
  }
}
```



# Statement coverage

measures whether given statement was executed at least one time

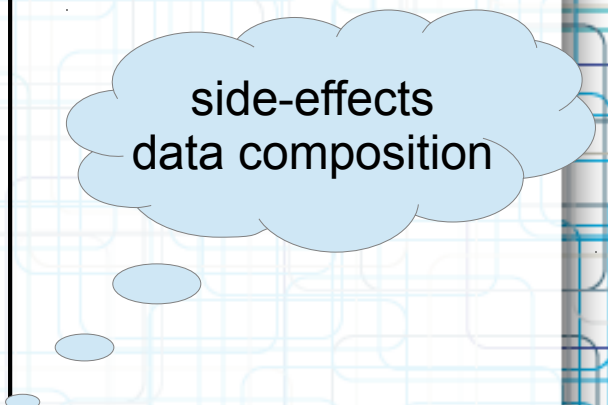
```
class StatementCoverage {

  static String foo(boolean b, int i) {
    String s;
    if (b) {
       s += "true";
    }
    if (i > 0) {
       s += "positive";
    } else {
       s += "negative or zero";
    }
    return s;
  }

  public static void main() {
    foo(true, 5);
    foo(false, 10);
  }
}
```



# Branch coverage

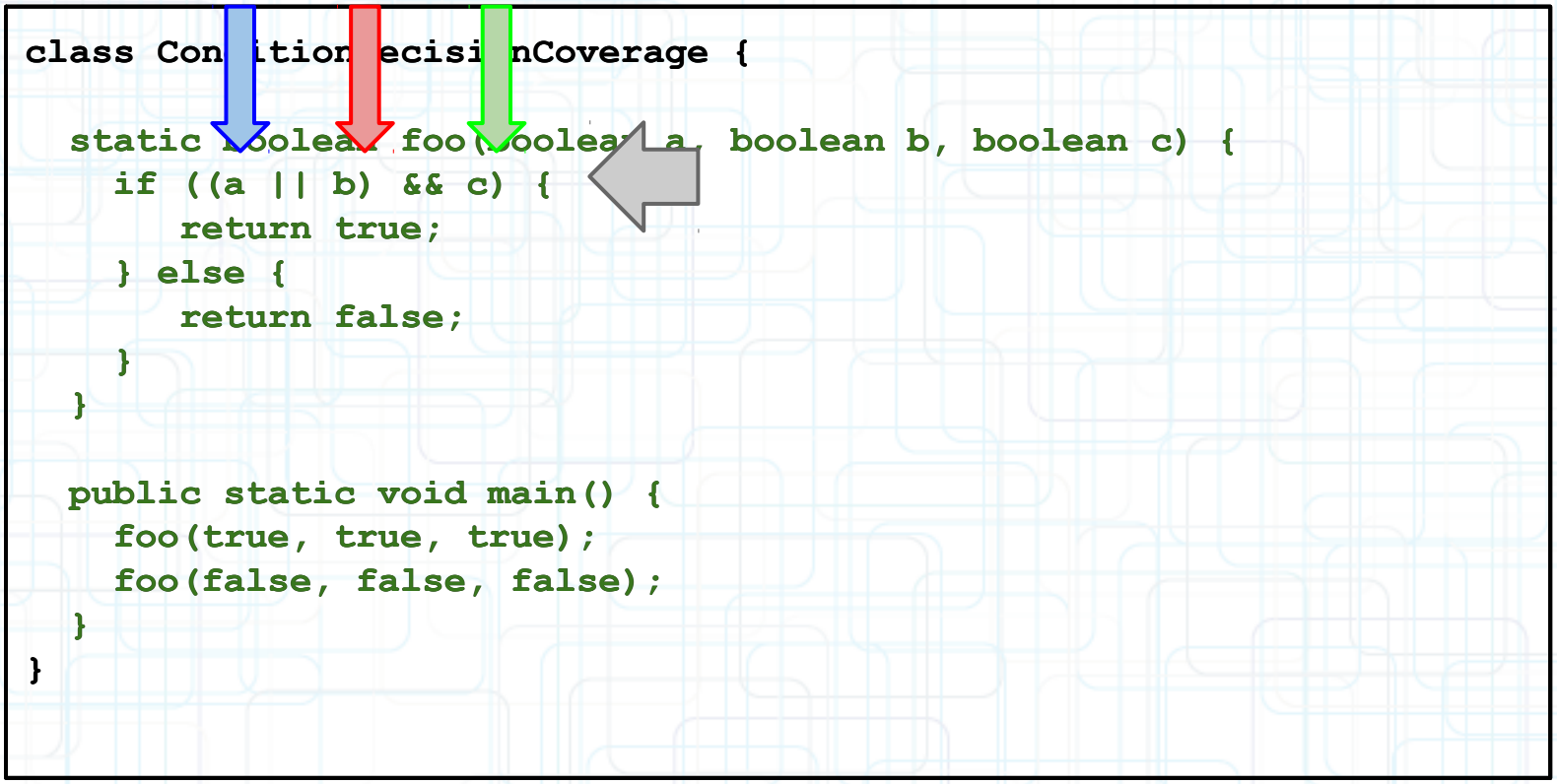
measures which possible branches in flow control structures are followed

```
class BranchCoverage {

  static String foo(boolean b, int i) {
    String s;
    if (b) { // true only
       s += "true";
    }
    if (i > 0) { // true & false
       s += "positive";
    } else {
       s += "negative or zero";
    }
  }

  public static void main() {
    foo(true, 0);
    foo(true, 10);
  }
}
```



# Condition / decision coverage

check every possible value of input condition and decision outcome



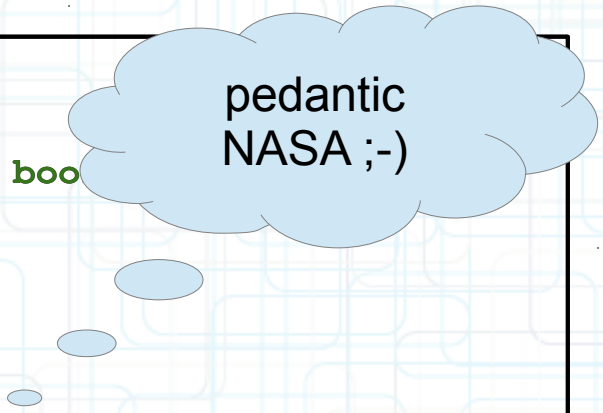
```
class ConditionDecisionCoverage {

  static boolean foo(boolean a, boolean b, boolean c) {
    if ((a || b) && c) {
       return true;
    } else {
       return false;
    }
  }

  public static void main() {
    foo(true, true, true);
    foo(false, false, false);
  }
}
```

# Modified condition / decision cov.

check every possible value of input condition and decision outcome

each condition has been shown to affect that decision **independently**

```
class ModifiedConditionDecisionCoverage {

  static boolean foo(boolean a, boolean b, boo
    if ((a || b) && c) {
       return true;
    } else {
       return false;
    }
  }

  public static void main() {
    foo(false, false, true);    // a,b are influencing
    foo(true, false, true);     // a,c are influencing
    foo(false, true, true);     // b,c are influencing
    foo(true, true, false);     // c is influencing
  }
}
```



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# Parsing Java
# ANTLR - grammar file structure

```
class JavaRecognizer extends Parser; // parser class name
/* grammar rules */
variableDefinitions
        :   variableDeclarator (COMMA! variableDeclarator)*
        ;

class JavaLexer extends Lexer; // lexer class name
/ * tokens */
COMMA         :   ',' {nc();};
IDENT
options {testLiterals=true;}
        : {nc();}   ('a'..'z'|'A'..'Z'|'_'|'$') ('a'..'z'|'A'..'Z'|'_'|'0'..'9'|'$')*
        ;
```

# Parsing Java
# ANTLR - running instrumentation

```
ANTLR: java.g => JavaLexer + JavaRecognizer

in = new InputStreamReader(new FileInputStream(sourceFile));
lexer = new JavaLexer(in);
filter = new CloverTokenStreamFilter(lexer);
parser = new JavaRecognizer(filter);
parser.compilationUnit();
filter.instrument(); // instrument the code
filter.write(out);   // write to output
```

# Parsing Java
# Definition of statement in ANTLR

```
statement [CloverToken owningLabel] returns [CloverToken last]
{
    CloverToken first = null;
    last = null;
}
    : {first = (CloverToken)LT(1);}
    (
    // if | for | while | throw etc ...
    |   "return" (expression)? SEMI!
    |   SEMI // empty statement
    )
        {
            if (last == null) {
                last = (CloverToken)LT(0);
            }
            instrumentStatementBefore(first, last);
        }
    ;
```

# Parsing Java
# Token stream filtering

```
CloverToken extends antlr.CommonHiddenStreamToken {
  // List<? extends Emitter> preEmitters;
  // addPreEmitter, triggerPreEmitters
}

class CloverTokenStreamFilter extends
antlr.TokenStreamHiddenTokenFilter {
  public void write(Writer outWriter) throws IOException {
    PrintWriter out = new PrintWriter(outWriter);
    CloverToken curr = this.first;
    while (curr != null) {
      curr.triggerPreEmitters(out);
      if (curr.getText() != null) out.print(curr.getText());
      curr = curr.getNext();
    }
  }
```

# Parsing Java
# Source code emitters

```
CloverToken instrumentStatementBefore(CloverToken start,
    CloverToken end) {
  start.addPreEmitter(new StatementInstrEmitter(...));
  return start;
}
class StatementInstrEmitter {
  String instr = "";
  StatementInstrEmitter(...) {
    info = db.addStatement(...);
    instr = "Recorder.inc(" + info.getDataIndex() + ");";
  }
  void emit(Writer out) throws IOException {
    out.write(instr);
  }
}
```

# Parsing Java
# Example: instrumenting statement

```
public IMoney add(IMoney m) {
  return m.addMoney(this);
}
```

```
public IMoney add(IMoney m) {
  try{ __CLR3_1_600hckkb3w8.R.inc(3);
  __CLR3_1_600hckkb3w8.R.inc(4);return m.addMoney(this);
  } finally {
    __CLR3_1_600hckkb3w8.R.flushNeeded();
  }
}
```

# Parsing Java
# Example: test method

```
public void testAdd() {
   ... some test code ....
}
```

```
public void testAdd() {
   __CLR3_1_67b7bhckkb42x.R.globalSliceStart(getClass().getName(), 263);
   java.lang.Throwable $CLV_t$ = null;
   try {
      ... some test code ...
   } catch (java.lang.Throwable $CLV_t2$) {
      $CLV_t$ = $CLV_t2$;
      __CLR3_1_67b7bhckkb42x.R.rethrow($CLV_t2$);
   } finally {
      __CLR3_1_67b7bhckkb42x.R.globalSliceEnd(
            getClass().getName(),"MoneyTest.testAdd", 263, $CLV_t$);
   }
}
```

# Parsing Groovy
# Groovyc build phases

INITIALIZATION
*source files are opened and environment configured*

PARSING
*the grammar is used to to produce tree of tokens representing the source code*

CONVERSION
*an abstract syntax tree (AST) is created from token trees*

SEMANTIC_ANALYSIS
*performs consistency and validity checks that the grammar can't check for, and resolves classes*

CANONICALIZATION
*complete building the AST*

**INSTRUCTION_SELECTION**
*instruction set is chosen, for example java5 or pre-java5*

CLASS_GENERATION
*creates the binary output in memory*

OUTPUT
*write the binary output to the file system*

FINALIZATION
*perform any last cleanup*

# Parsing Groovy
# Groovy's AST (1)

```
my.jar/META-INF/services/
org.codehaus.groovy.transform.ASTTransformation:
com.acme.MyGroovy


@GroovyASTTransformation (phase =
CompilePhase.INSTRUCTION_SELECTION)
public class MyGroovy implements ASTTransformation {
  public void visit(ASTNode[] astNodes, SourceUnit sourceUnit) {
    for (ClassNode clazz : sourceUnit.getAST().getClasses()) {
      new MyTransformer(sourceUnit, clazz).visitClass(clazz);
    }
  }
}
```

# Parsing Groovy
# Groovy's AST (2)

```
public class MyTransformer extends ClassCodeExpressionTransformer {
  public Expression transform(Expression expr) {
    Expression transformed = super.transform(expr);
    if (transformed instanceof ElvisOperatorExpression)
       transformed = transformElvis((ElvisOperatorExpression)transformed);
    transformed.setSourcePosition(expr);
    return transformed;
  }

  private Expression transformElvis(ElvisOperatorExpression elvis) {
    transformed = new ElvisOperatorExpression(
        new StaticMethodCallExpression(this.currentClass,
            "elvisEvalWrapper",
            new ArgumentListExpression(
                elvis.getTrueExpression(),
                new ConstantExpression(getDataIndex(elvis)))),
        elvis.getFalseExpression());
    return transformed;
  }
}
```

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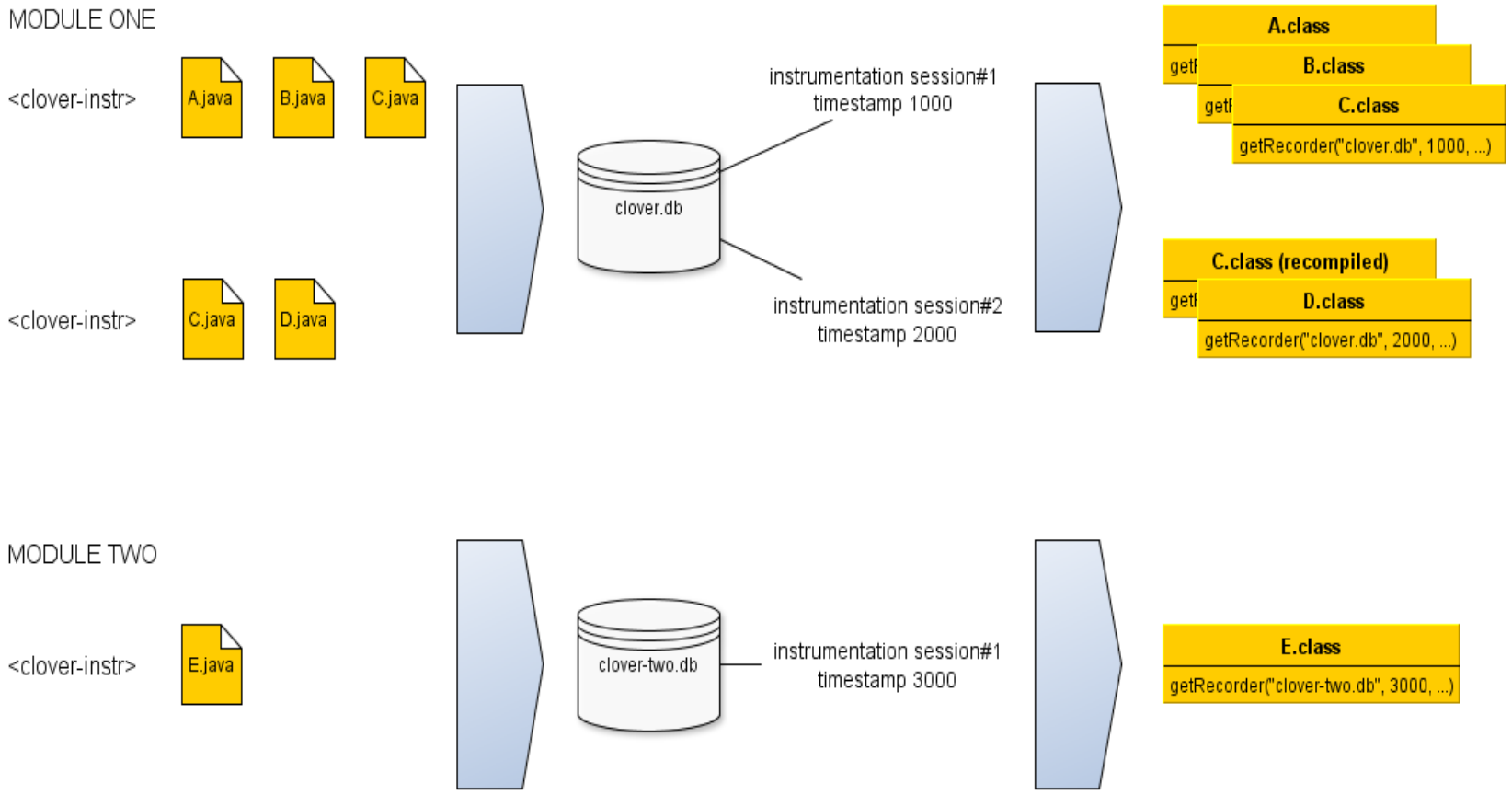
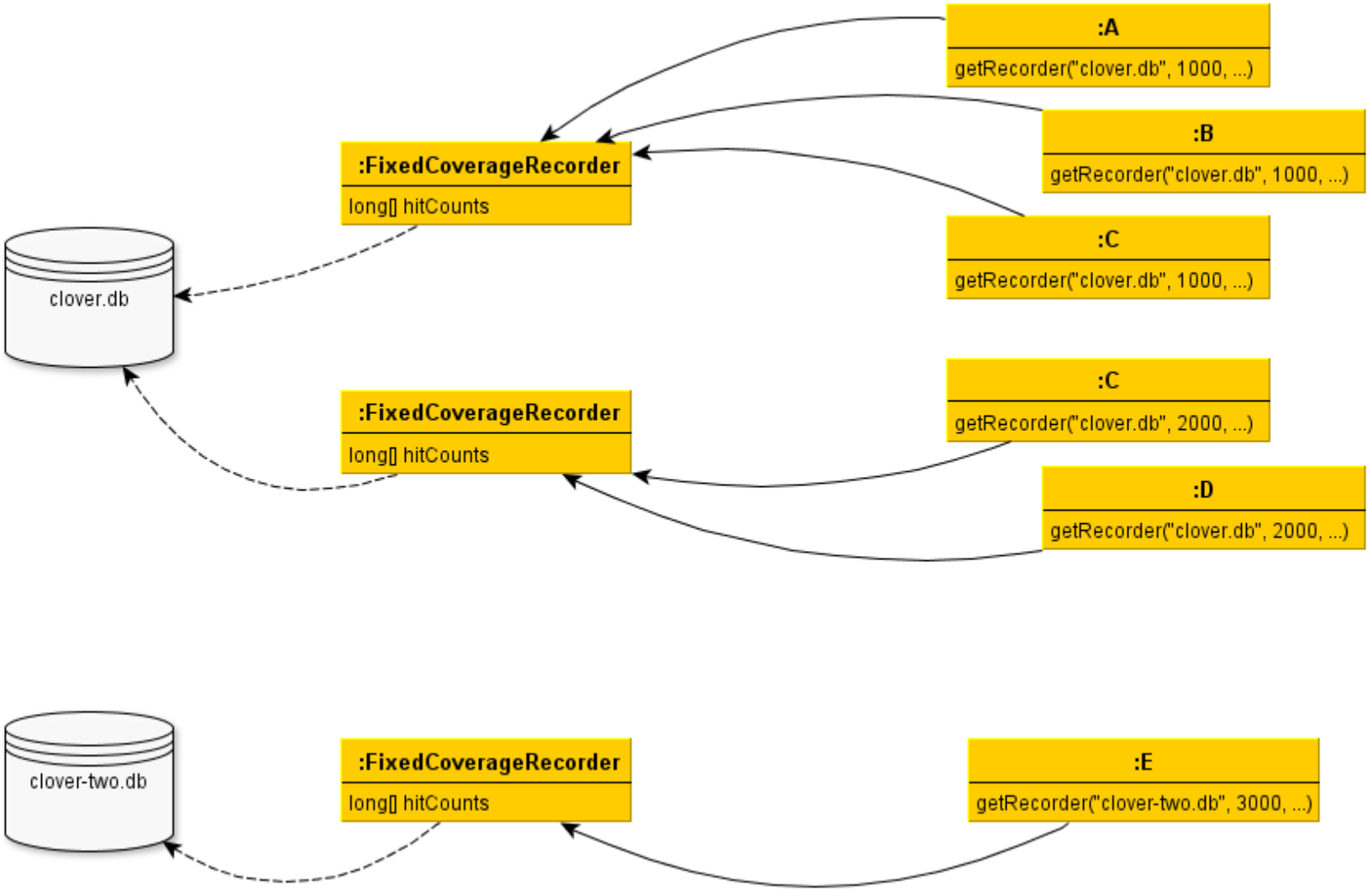
# Clover's coverage recorders

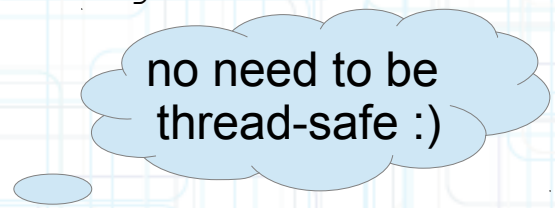


# Clover's coverage recorders



# Multi-threaded applications

```
public class CoverageRecorder {
    private final int[] elements;
    private final PerTestRecorder testCoverage;
    // ...
    public void inc(int index) {
        testCoverage.set(index);
        elements[index]++;
    }
}
```

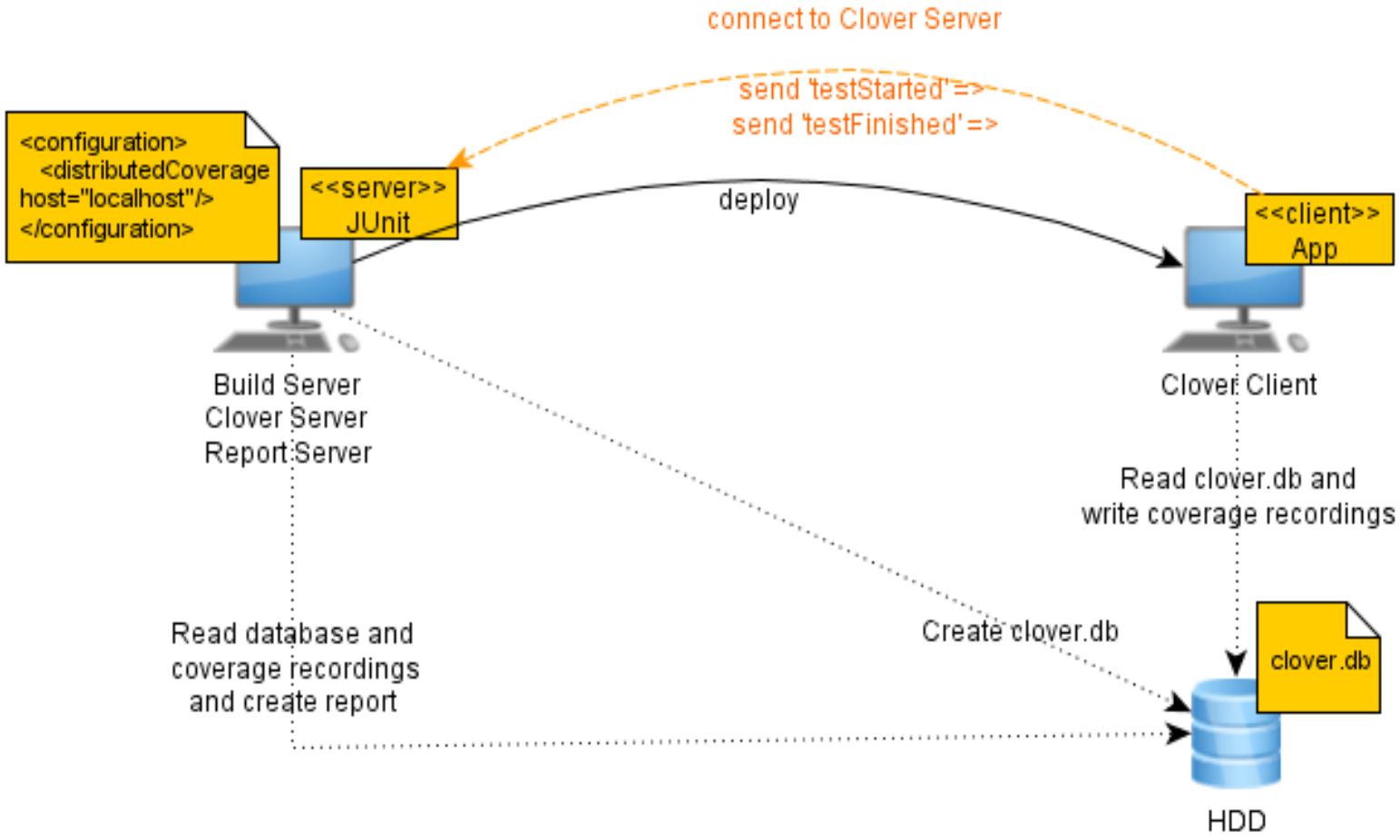


# Multi-threaded tests

- keep pool of active per-test recorders
  - goal: achieve maximum performance
  - volatile implementation in JDK1.4 sucks
- per-test recording strategies
  - single-threaded (no synchronization)
  - volatile (JDK1.5+)
  - synchronized blocks

```
public static class Volatile implements ThreadVisibilityStrategy {
    private volatile ActivePerTestRecorderAny recorders; /* a pool of recorders */
    public Volatile(CoverageRecorder coverageRecorder) {
        recorders = new ActivePerTestRecorderNone(coverageRecorder);
    }
    public synchronized void testStarted(int testRunId) { /* memory barrier flush. */
        recorders = recorders.testStarted(testRunId);
    }
    public synchronized LivePerTestRecording testFinished(int testRunId, ErrorInfo ei) {
        RecordingResult sliceAndRecorders = recorders.testFinished(testRunId, ei);
        recorders = sliceAndRecorders.recorders;
        return sliceAndRecorders.recording;
    }
    public void inc(int index) {  /* no 'synchronized' */
        recorders.inc(index);
    }
}
```

# Multiple JVMs



# Questions

?

# Thank you

Clover: http://www.atlassian.com/software/clover

Contact: mparfianowicz@atlassian.com

# BACKUP SLIDES

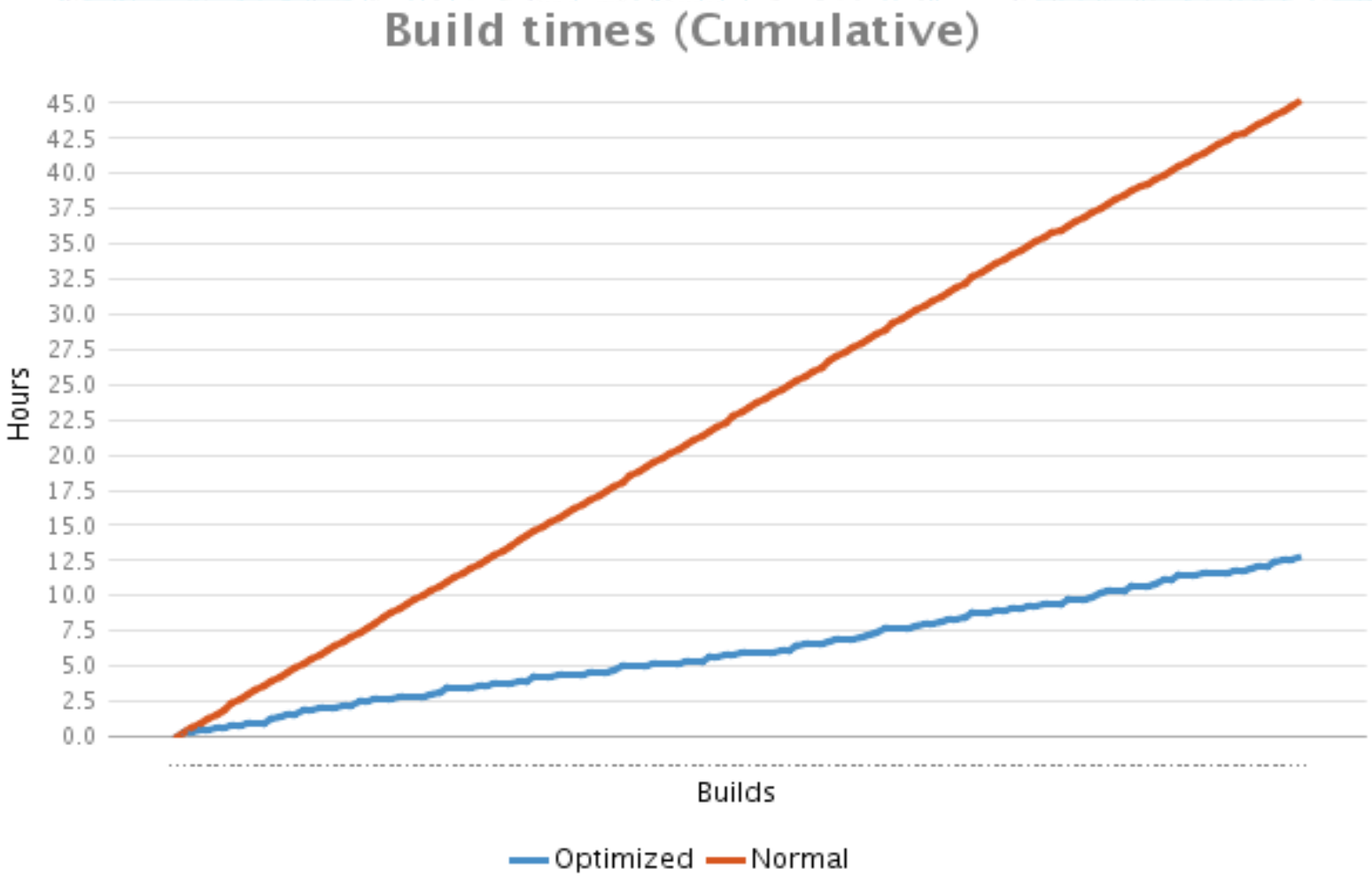
# Atlassian dogfooding

- Clover with Clover
  - ca 60% coverage in total
  - 80-90% in core modules
- Bamboo with Clover
  - in a separate plan, supplementary
- JIRA with Clover
  - very limited usage as Clover does not measure coverage for JavaScript

# Clover reporting features

- Top risks
- Quick wins
- Coverage map
- Test contribution
- Class complexity
- Code metrics

# Test optimization




https://confluence.atlassian.com/display/CLOVER/About+Test+Optimization

# Android platform

Dalvik VM

- instrumentation is quite trivial in Clover
- limit of 65k methods in one image
- no bytecode manipulation
  - java, scala – ok
  - groovy – not possible

Clover-for-Android alpha

https://confluence.atlassian.com/display/CLOVER/Clover-for-Android

# Tool integrations