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The Lord of the Strings

«How I spent my summer»

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Intro

Intro: Expectations

This talk is mostly about the JDK/JVM development experience for 2 features:

- **Compact Strings**: represent ASCII Strings with 1 byte/char
- **Indify String Concat**: move the String concat to run time

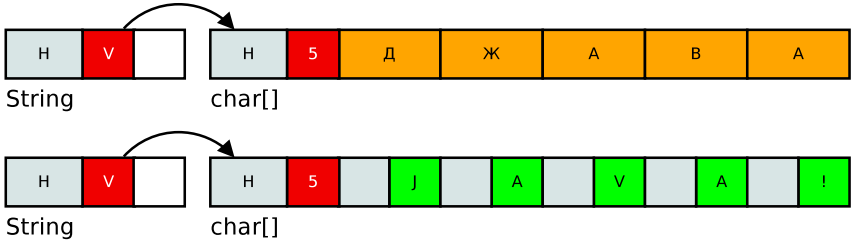
For each feature, we have three parts:

1. **Insight**: main idea and elevated hope
2. **Angst**: how many angels are dancing on JDK development pin
3. **Catarsis**: what this pain gives us in return

Or, «Why those [expletive] [expletive] [expletive] cannot do the feature in a month, but spend a year instead»[citation needed]

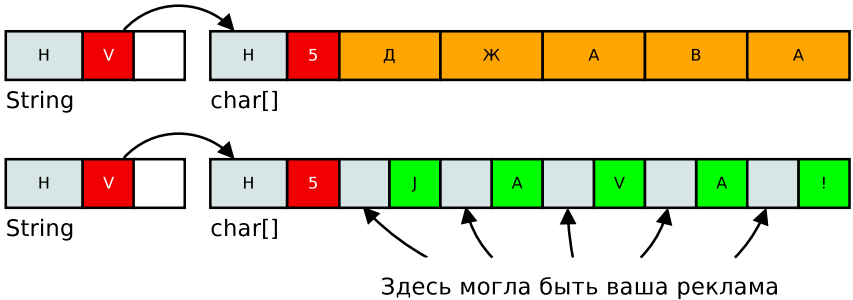
Compact Strings

Compact Strings: String internals



- Two objects: `String` и `char[]`
- Anything we can cut?

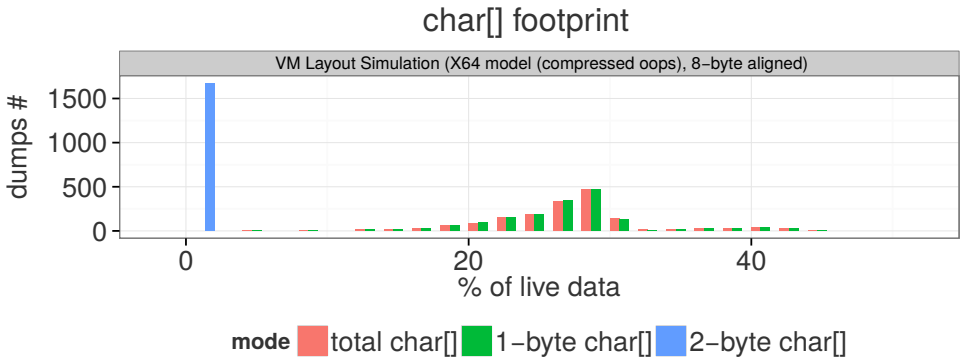
Compact Strings: String internals



- Lots of zeroes in those `char[]`-s
- Mostly, because an overwhelming number of `String`-s is Latin1

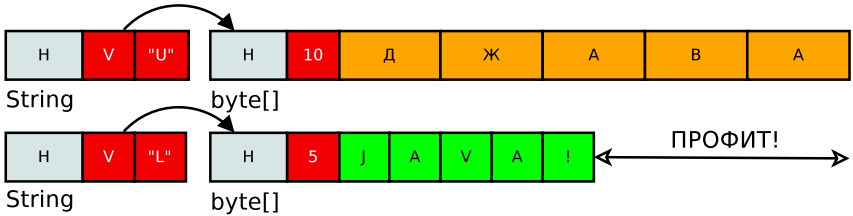
Compact Strings: Some RealWorld (tm) Data

Most applications have lots of `Strings`, most of them are Latin1:



Compact Strings: Wouldn't It Be Awesome...

...if `String`-s were like that:



- Don't store `char[]`, store `byte[]`
- The `String` itself is aware what «coder» to use for deciphering the data

Compact Strings: Thou Shalt Not Regress

Lots and lots of `charAt` calls in JDK:

```
# find -iname \*.java -exec grep charAt {} \; | wc -l
2157
```

Simplest use case:

```
for (int i = 0; i < s.length(); i++) {
   char c = s.charAt(i);
   System.out.println(c);
}
```


Compact Strings: Bird's Eye View

- String is compressed during construction
  - The largest trouble: `String(char[] value)` constructor
  - Optimistically try to compress in 1-byte. Failed? Copy as 2-byte...
  - Some shortcuts are possible, e.g. ISO-8851-1 fastpath

- Methods are able to operate on both 1-byte and 2-byte forms
  - `substring` for a 1-byte String is also 1-byte
  - `String(String other)` constructor does not repack
  - `char[] getChars()` needs to copy/unpack

Compact Strings: JDK Development In 5 Easy Steps

1. Check out the workspace
2. Hack, hack, hack

```
sed -i -e "s/char[]/byte[]/g" \
    java/lang/String.java
```

3. Run the tests
4. Fix the bugs (a few `if`s here and there)
5. BIKESHED A LOT

Who codes the coders?

CS, Coders: OOP

Reference a «coder» implementation:

- Almost idiomatic OOP!
- Quadratisch.
- Praktisch.
- Gut.

Problems?

```
class String {
  byte[] val;
  Coder coder;

  char charAt(int idx) {
    return coder.charAt(val, idx);
  }
}

interface Coder {
  char charAt(byte[] val, int idx);
}
```


CS, Coders: Object?

Masking `byte[]` or `char[]`:

- «Ever so slight» step away from OOP idiomatics
- Typechecks are cheap, right?

Problems?

```
class String {
  Object val;
  char charAt(int idx) {
    // FIXME: Range checks!
    if (val instanceof byte[]) {
      byte[] v = (byte[])val;
      return toChar(v[idx]);
    } else {
      // Totally safe!
      char[] v = (char[])val;
      return v[idx];
    }
  }
}
```


CS, Coders: Hide Me Under The Tree

Hide coder as zero-th element:

- Oh wow, it's like Pascal all over again!
- Seriously, we can just compare the arrays now

Problems?

```
class String {
  byte[] val;
  char charAt(int idx) {
    // FIXME: Range checks!
    byte coder = val[0];
    if (coder == LATIN1) {
      return toChar(val[idx + 1]);
    } else {
      return toChar(
         (val[idx*2] << 8)
               + val[idx*2+1]);
    }
  }
}
```

CS, Coders: Tagged Arrays

Steal a bit from address, maybe?

- We are... RUNTIME.
- We can do whatever the hell we want

Problems?

```
class String {
  byte[] val;
  char charAt(int idx) {
    // FIXME: Range checks!
    byte coder = VM_MAGIC(val);
    if (coder == LATIN1) {
      return val[idx];
    } else {
      return getChar(val, idx);
    }
  }
}
```


CS, Coders: Thou Shalt Not Overcomplicate

```
***** 32-bit VM: ************************************************
java.lang.String object internals:
 OFFSET  SIZE   TYPE DESCRIPTION                    VALUE
      0     8        (object header)                N/A
      8     4 char[] String.value                   N/A
     12     4    int String.hash                    N/A
Instance size: 16 bytes

***** 64-bit VM, compressed references enabled: *****************
java.lang.String object internals:
 OFFSET  SIZE   TYPE DESCRIPTION                    VALUE
      0    12        (object header)                N/A
     12     4 char[] String.value                   N/A
     16     4    int String.hash                    N/A
     20     4        (loss due to the next object alignment)
Instance size: 24 bytes
```


CS, Coders: Just A Field

Coder is binary:

- 0 - Latin1, «all high bytes are zero»
- 1 - UTF16, «at least one high byte is not zero»

Allows you do to tricks:

- Compare Strings without touching `val`
- Concat result coder = «OR» over argument coders

```
class String {
  byte[] val;
  byte coder;
  char charAt(int idx) {
    // FIXME: Range checks!
    if (coder == LATIN1) {
      return val[idx];
    } else {
      return getChar(val, idx);
    }
  }
}
```


CS, Coders: In Much More Detail

Magnum Opus on method dispatch performance:
`http://shipilev.net/blog/2015/black-magic-method-dispatch/`

More details on choosing where to put coders:
`http://cr.openjdk.java.net/~shade/density/double-selection.txt`

Stable zero and other perversions

CS, Zeroes: What Kind of Sourcery Is This?

Why is this optimized like that?

```
static final String S;

static {
  S = "Foo";
}

@Benchmark
int testLength() {
  return S.length();
}
```

```
testLength():
  # ... some mumbo-jumbo ...
  # THE ANSWER IS "3"!
  mov $0x3$, %eax
  # ... some mumbo-jumbo ...
  ret
```


CS, Zeroes: Truth or Dare

```
static final MyClass finallie    = new MyClass();
static       MyClass nonFinallie = new MyClass();

class MyClass {
  final int trustMe = 42;
}

int read_finallie() {
  return finallie.trustMe; // folded to "42", or not?
}

int read_nonFinallie() {
  return nonFinallie.trustMe; // folded to "42", or not?
}
```


CS, Zeroes: Truth or dare

```
static final MyClass finallie = new MyClass();

class MyClass {
  @Stable
  final int trustMe = 42;
}

int read_finallie() {
  return finallie.trustMe; // folded to "42", or not?
}
```


CS, Zeroes: Truth or Dare

```
class String {
  @Stable final byte coder;
  @Stable final byte[] value;
  int length() { return value.length >> coder);
}

int len_Latin1() {
  return "Foo".length(); // folded or not?
}

int len_UTF16() {
  return "Φyy".length(); // folded or not?
}
```


CS, Zeroes: Gonna Try Something Else

- Find the compiler's stash of trusted classes
- Find the special treatment for `final` fields in those classes
- Add `String` to trust its `final` fields

Feature Kill Switch:
`-XX:-CompactStrings`

CS, Kill Switch: Naively...

```
class String {
  static final boolean COMPACT_STRINGS = ...;

  String(char[] value) {
     if (COMPACT_STRINGS) {
        byte[] v = tryCompress(value);
        if (v != null) {
           this.value = v; this.coder = LATIN1; return;
        }
     }
     this.value = copy(value); this.coder = UTF16;
  }
}
```


CS, Kill Switch: Working...

```
class String {
  static final boolean COMPACT_STRINGS = ...;

  char charAt(int idx) {
    if (coder == LATIN1) { // branch, nevertheless
      return val[idx];
    else
      return getChar(val, idx);
  }
}
```

Everything is awesome, everyone is coming with `(coder == UTF16)`?

CS, Kill Switch: Working...

```
class String {
  static final boolean COMPACT_STRINGS = ...;

  char charAt(int idx) {
    if ((coder == LATIN1) && COMPACT_STRINGS) {
      return val[idx];
    else
      return getChar(val, idx);
  }
}
```

Compilers are good at folding, right?

CS, Kill Switch: Working...

```
class String {
  static final boolean COMPACT_STRINGS = ...;

  char charAt(int idx) {
    if (COMPACT_STRINGS && (coder == LATIN1)) {
      return val[idx];
    else
      return getChar(val, idx);
  }
}
```

Nope... only this one works reliably.[1]

[1] https://bugs.openjdk.java.net/browse/JDK-8087309

CS, Kill Switch: Working...

```
class String {
  static final boolean COMPACT_STRINGS = ...;
  boolean isLatin1() { return COMPACT_STRINGS && (coder == LATIN1); }

  char charAt(int idx) {
    if (isLatin1()) {
      return val[idx];
    else
      return getChar(val, idx);
  }
}
```

Or this?

CS, Kill Switch: Will This Work?

```
class String {
  static final boolean COMPACT_STRINGS =
    Boolean.getBoolean("compactStrings");
}
```


CS, Kill Switch: Will This Work?

```
class String {
  static final boolean COMPACT_STRINGS =
    Boolean.getBoolean("compactStrings");
}
```

Circular dependencies:

```
Error occurred during initialization of VM
java.nio.charset.IllegalCharsetNameException: UTF-8
at java.nio.charset.Charset.checkName(Charset.java:316)
    ...
at java.lang.StringCoding.decode(StringCoding.java:334)
at java.lang.String.<init>(String.java:592)
at java.lang.String.<init>(String.java:614)
at java.lang.System.initProperties(Native Method)
at java.lang.System.initializeSystemClass(System.java:1162)
```


CS, Kill Switch: What About This One?

```
class String {
  static final boolean COMPACT_STRINGS =
    Unsafe.isCompactStrings();
}
```


CS, Kill Switch: What About This One?

```
class String {
  static final boolean COMPACT_STRINGS =
    Unsafe.isCompactStrings();
}
```

Even better...

```
# A fatal error has been detected by the JRE:
#
#  SIGSEGV (0xb) at pc=0x0000000000000000, pid=..., tid=...
#
# JRE version:  (9.0) (build ...)
# Java VM: OpenJDK 64-Bit Server VM ...
# Problematic frame:
# C  0x0000000000000000
```


CS, Kill Switch: It's ALIVE!

```
class String {
  static final boolean COMPACT_STRINGS = isCompactStrings();
  private static native boolean isCompactStrings();
}

JNIEXPORT jboolean JNICALL
Java_java_lang_String_isCompactStrings(JNIEnv *env, jclass cls) {
    return JVM_IsCompactStrings();
}

JNIEXPORT jboolean JNICALL JVM_IsCompactStrings(void) {
  JVMWrapper("JVM_IsCompactStrings");
  return CompactStrings;
}
```


CS, Kill Switch: Will This Do?

```
class String {
  static final boolean COMPACT_STRINGS = true;
}

void VM::super_secret_VM_method() {
  find_String_field_and_set_it_to(CompactStrings);
}
```


CS, Kill Switch: Or This?

```
class String {
  static final boolean COMPACT_STRINGS =
    new Boolean(true).booleanValue();
}

void VM::super_secret_VM_method() {
  find_String_field_and_set_it_to(CompactStrings);
}
```


Arrays of Trickery Ahead

CS, Arrays: `char[]`

```
char[] tryWithChar(int size) {
  return new char[size];
}
```

What `size` would fail?

CS, Arrays: char[]

```
char[] tryWithChar(int size) {
  return new char[size];
}
```

What size would fail?

```
tryWithChar(Integer.MAX_VALUE):
```

```
Exception in thread "main" java.lang.OutOfMemoryError:
Requested array size exceeds VM limit
at org.openjdk.BoundsTest.testWith(BoundsTest.java:30)
at org.openjdk.BoundsTest.main(BoundsTest.java:25)
```


CS, Arrays: char[]

```
char[] tryWithChar(int size) {
  return new char[size];
}
```

What size would fail?

```
tryWithChar(Integer.MAX_VALUE - 2); // works
```


CS, Arrays: String

```
String tryWithString(int size) {
  return new String(new char[size]);
}
```

```
tryWithString(Integer.MAX_VALUE - 2):
```


CS, Arrays: String

```
String tryWithString(int size) {
  return new String(new char[size]);
}
```

```
tryWithString(Integer.MAX_VALUE - 2):
```

```
java.lang.OutOfMemoryError:
UTF16 String size is 2147483645, should be less than 1073741807
at java.lang.StringUTF16.rangeCheck(StringUTF16.java:56)
at java.lang.StringUTF16.compress(StringUTF16.
```


getChar,
or `char[]` view over `byte[]`, anyone?

CS, getChar: What Could Possibly Be Simpler

```
char getChar_UTF16(byte[] val, int idx) {
  idx *= 2;
  return toChar(val[idx]) + toChar(val[idx + 1]) << 8;
}
```


CS, getChar: What Could Possibly Be Simpler

```
char getChar_UTF16(byte[] val, int idx) {
  idx *= 2;
  return toChar(val[idx]) + toChar(val[idx + 1]) << 8;
}
```

Endianness, you freakish hardware you?

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Endianness, you freakish hardware you?

```
char getChar_UTF16(byte[] val, int idx) {
  idx *= 2;
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}
```


CS, getChar: Running With Scissors

```
// Got a hammer:
static final Unsafe U = Unsafe.getUnsafe();
static final int base = U.ARRAY_CHAR_BASE_OFFSET;
static final int scale = U.ARRAY_CHAR_INDEX_SCALE;

// Everything looks like a nail:
char getChar_UTF16(byte[] val, int idx) {
  return U.getChar(val, base + scale*idx);
}
```


CS, getChar: Running With Scissors

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// Got a hammer:
static final Unsafe U = Unsafe.getUnsafe();
static final int base = U.ARRAY_CHAR_BASE_OFFSET;
static final int scale = U.ARRAY_CHAR_INDEX_SCALE;

// Everything looks like a nail:
char getChar_UTF16(byte[] val, int idx) {
  return U.getChar(val, base + scale*idx);
}
```

Hint:

$$\lim_{idx \to MAX} getChar(val, idx) =< garbage >$$

CS, getChar: Running With Longer Scissors

```
// Got a longer hammer:
static final Unsafe U = Unsafe.getUnsafe();
static final long base = U.ARRAY_CHAR_BASE_OFFSET;
static final long scale = U.ARRAY_CHAR_INDEX_SCALE;

// Everything looks like a longer nail:
char getChar_UTF16(byte[] val, int idx) {
  return U.getChar(val, base + scale*idx);
}
```

[2] https://bugs.openjdk.java.net/browse/JDK-8074124

CS, getChar: Running With Longer Scissors

```
// Got a longer hammer:
static final Unsafe U = Unsafe.getUnsafe();
static final long base = U.ARRAY_CHAR_BASE_OFFSET;
static final long scale = U.ARRAY_CHAR_INDEX_SCALE;

// Everything looks like a longer nail:
char getChar_UTF16(byte[] val, int idx) {
  return U.getChar(val, base + scale*idx);
}
```

Except that 32-bit platforms are down:[2]

```
UnsafeConvBench.plain                3835.953 ± 48.240 ns/op
UnsafeConvBench.unsafe_field_scale   7611.268 ± 72.331 ns/op
```

[2] https://bugs.openjdk.java.net/browse/JDK-8074124

CS, getChar: Recap

`(get|put)Char` problems are solvable with three options:

1. Make compiler prove no overflow in regular expressions

2. Drill more holes in `Unsafe`

```
<T> T Unsafe.get_T_Indexed(Object,int)
```

3. Make more intrinsics in C1 and C2:

```
char StringUTF16.getChar(byte[] val, int idx)
void StringUTF16.putChar(byte[] val, int idx, char c)
```


What Is Left?: ...and few things

- Redo the same for all important `String` methods
- Redo the same for other platforms
- Fix up VM support for native `Stringss`
- Moar Intinriscs for Intrinsics GOD
- Encoders/Decoders handling for new `String` forms
- Fix up library: `AbstractStringBuilder`-s!
- Fix up `-XX:+OptimizeStringConcat`

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CS, Catharsis: LogLineBench

```
public class LogLineBench {
  @Param
  int size;

  String method = generateString(size);

  @Benchmark
  public String work() throws Exception {
      return "[" + System.nanoTime() + "] " +
             Thread.currentThread().getName() + ":" +
             "Calling an application method \"" + method +
             "\" without fear and prejudice.";
  }
}
```


CS, Catharsis: Performance

	throughput, ns/op			allocated, b/op		
	1	10	100	1	10	100
8u66 Baseline	148 ± 2	147 ± 2	227 ± 3	888	904	1680
9b92 Baseline	149 ± 3	153 ± 4	231 ± 4	888	904	1680
9b93 -XX:-CompactStrings	152 ± 3	150 ± 4	230 ± 6	888	904	1680
9b103 -XX:-CompactStrings	132 ± 4	135 ± 6	224 ± 4	888	904	1680
9b93 -XX:+CompactStrings	142 ± 2	139 ± 3	169 ± 4	504	512	904
9b103 -XX:+CompactStrings	130 ± 5	130 ± 4	155 ± 6	504	512	904

- 1.36x better throughput, 1.85x less garbage
- Kill Switch is working, for the cases when something goes wrong

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Indify String Concat

Indify String Concat: See Any Concat In Bytecode?

```
String m(String a, int b) {  return a + "(" + b + ")"; }
```


Indify String Concat: See Any Concat In Bytecode?

```
String m(String a, int b) {  return a + "(" + b + ")"; }
```

```
 0: new           #2   // class java/lang/StringBuilder
 3: dup
 4: invokespecial #3   // Method java/lang/StringBuilder."":()V
 7: aload_1
 8: invokevirtual #4   // Method java/lang/StringBuilder.append:(Ljava/lang
11: ldc           #5   // String (
13: invokevirtual #4   // Method java/lang/StringBuilder.append:(Ljava/lang
16: iload_2
17: invokevirtual #6   // Method java/lang/StringBuilder.append:(I)Ljava/la
20: ldc           #7   // String )
22: invokevirtual #4   // Method java/lang/StringBuilder.append:(Ljava/lang
25: invokevirtual #8   // Method java/lang/StringBuilder.toString:()Ljava/l
28: areturn
```

Indify String Concat: OptimizeStringConcat

Compiler is not stupid, it has `-XX:+-OptimizeStringConcat`[3]

1. Match the IR for something that looks like a sane `StringBuilder::append` and `StringBuider::toString` chains
2. Squeak happily, and replace the entire thing with:
   - Compute the argument(s) lengths, and result length
   - Allocate the storage
   - Do the in-place copies, where possible, e.g. `Integer.getChars(...)`
   - Do the efficient arraycopies for `Strings`
3. Profit!

[3] `http://hg.openjdk.java.net/jdk9/jdk9/hotspot/file/tip/src/share/vm/opto/stringopts.cpp`

Indify String Concat: Caveat #1: «Transparency»

```
int next() { return (id++) & 0xFF };

@Benchmark
public String infix() {
  return "Hello, sir, your SS number is " + next() +
    ", and you have a problem with your tax report.";
}

@Benchmark
public String prefix() {
  int luckyBoy = next();
  return "Hello, sir, your SS number is " + luckyBoy +
    ", and you have a problem with your tax report.";
}
```


Indify String Concat: Caveat #1: «Transparency»[4]

```
int x;

// Optimizeable:
new StringBuilder().append("Foo: ").append(x).toString();

// NOPE. NOPE. NOPE.
new StringBuilder().append("Foo: ").append(x++).toString();

// Optimizeable again:
x++;
new StringBuilder().append("Foo: ").append(x).toString();
```

[4] https://bugs.openjdk.java.net/browse/JDK-8043677

Indify String Concat: Caveat #2: «Universality»

```
int i;
long l;
double d;

// Optimizeable:
new StringBuilder().append("Foo: ").append(i).toString();

// NOPE, LOL
new StringBuilder().append("Foo: ").append(l).toString();

// YOUR WISH, BROTHA, ROFL
new StringBuilder().append("Foo: ").append(d).toString();
```


Indify String Concat: Caveat #3: «Reliability»[5]

```
String s1, s2;

// JDK 9 Baseline, optimizeable:
new StringBuilder(s1.length() + s2.length())
    .append(s1).append(s2).toString();

// JDK 9 Compact Strings... NOPE, WHAT ARE U DOIN', STAHP
class String {
  int length() { return value.length >> coder; }
}

new StringBuilder(s1.length() + s2.length())
    .append(s1).append(s2).toString();
```

[5] https://bugs.openjdk.java.net/browse/JDK-8136469

Indify String Concat: Insight

Want to match runtime support?
You **have to** control the bytecode.

How to hande this mess? Let's change the bytecode emitted by `javac`, d'uh:

- Ask users to recompile with newer `javac`?
- It is easy to make a simple «mistake» in bytecode, so that compiler would be unable to match
- M bytecode variants, N compiler versions
  $\Rightarrow$ M*N configurations to test

Indify String Concat: Late Binding

Level out the impedance between the Java *language* and Java *bytecode*.
If only we could delay the decision on what concat really does:

```
package java.lang;

class StringConcat {
  String concat(String first, String... moar) {
    // TODO: Actually implement this.
  }
}
```


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```

Dang it, this only works with Strings...

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```

Dang it, boxing. Dang it, allocating for varargs...

Indify String Concat: `invokedynamic` magic

```
String m(String a, int b) {  return a + "(" + b + ")"; }
```


Indify String Concat: `invokedynamic` magic

```
String m(String a, int b) {  return a + "(" + b + ")"; }

java.lang.String m(java.lang.String, int);
  0: aload_1
  1: ldc           #2       // String (
  3: iload_2
  4: ldc           #3       // String )
  6: invokedynamic #4,  0   // InvokeDynamic #0:makeConcat
                            //   (String,String,int,String)String
 11: areturn

BootstrapMethods:
  0: #19 invokestatic java/lang/invoke/StringConcatFactory.makeConcat...
```


Indify String Concat: `invokedynamic` magic, #2

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String m(String a, int b) {  return a + "(" + b + ")"; }
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Indify String Concat: `invokedynamic` magic, #2

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String m(String a, int b) {  return a + "(" + b + ")"; }
```
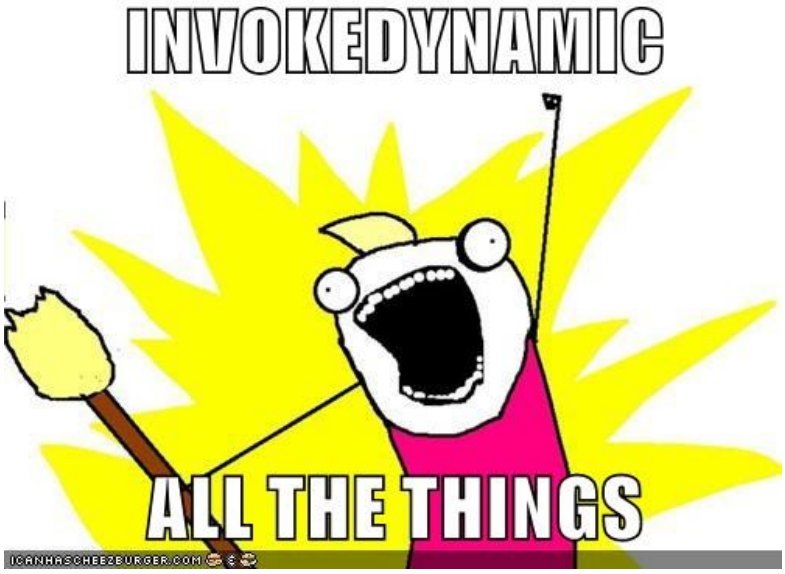

```
java.lang.String m(java.lang.String, int);
  0: aload_1
  1: iload_2
  2: invokedynamic #2,  0   // InvokeDynamic #0:makeConcat
                            //   (String,int)String;
  7: areturn

BootstrapMethods:
  0: #15 invokestatic
  java/lang/invoke/StringConcatFactory.makeConcatWithConstants:..
    Method arguments:
      #16 \u0001(\u0001)
```

ISC, Init: Oops

```
Error occurred during initialization of VM
java.lang.StackOverflowError
at java.lang.Throwable.toString(Throwable.java:481)
at java.lang.BootstrapMethodError.<init>(BootstrapMethodError.java:77
at java.lang.Throwable.toString(Throwable.java:481)
...
at sun.nio.cs.StandardCharsets.lookup(StandardCharsets.java:1100)
at sun.nio.cs.StandardCharsets.charsetForName(StandardCharsets.java:1
```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```

Concat needs `java.lang.invoke`, that uses concat, that needs `java.lang.invoke`, that uses concat, that needs `java.lang.invoke`, that uses concat, that needs `java.lang.invoke`, ...

ISC, Init: Thank You, Dear Jigsaw

Before JEP 201 «Modular Source Code»[6]:

1. `java.lang.invoke` can potentially call anything in JDK
2. Ergo, no JDK classes are allowed to use Indy String Concat

[6] `http://openjdk.java.net/jeps/201`

ISC, Init: Thank You, Dear Jigsaw

Before JEP 201 «Modular Source Code»[6]:

1. `java.lang.invoke` can potentially call anything in JDK
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After JEP 201:

1. `java.lang.invoke` can potentially call anything in `java.base`
2. Ergo, no `java.base` class can use Indy String Concat
3. Thank You, Dear Jigsaw!

[6] `http://openjdk.java.net/jeps/201`

But the initial `invokedynamic` linkage should cost us something? How's startup?

ISC, Startup: Hello Cruel String Concat World

```
public class Concat {
  static String a = "a";
  static String b = "b";
  static String c = null;
  static int d = 42;

  public static void main(String... args) {
    System.out.println(a + b + c + d + null);
  }
}
```


ISC, Startup: Take This `HelloWorld` Example

JDK 9 Baseline:

```
-XstringConcat:inline:  200.1 ± 1.5 ms
-XstringConcat:indy:    201.2 ± 2.0 ms
```

Very nice! El-cheapo `java.lang.invoke`!

[7] `https://bugs.openjdk.java.net/browse/JDK-8136854`

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Oh shi... G1 performance bug.[7]

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```

Very nice! El-cheapo `java.lang.invoke`!
Oh shi... G1 performance bug.[7]

`-XX:+UseParallelGC`:

```
-XstringConcat:inline:  31.1 ± 1.5 ms
-XstringConcat:indy:    58.5 ± 2.0 ms
```

[7] https://bugs.openjdk.java.net/browse/JDK-8136854

ISC, Startup: Hello Cruel String Concat World, #2

```
public class Concat2 {
  static String a = "a";
  static String b = "b";
  static String c = null;
  static int d = 42;

  public static void main(String... args) {
    System.out.println(a + b + c + d + null);         // 1
    System.out.println(a + b + c + d + null + null); // 2
  }
}
```

```
(1):    58.5 ± 2.0 ms
(1+2):  59.5 ± 2.0 ms
```


ISC, Startup: Necessary Evil?

First `invokedynamic` user pays for everyone:[8]

- Indify String Concat
- Lambda MetaFactory
- Nashorn, JRuby
- Jigsaw

Early Bird Gets All The Regression Bugs

[8] `https://bugs.openjdk.java.net/browse/JDK-8086045`

ISC, Strategies: Basic

***_SB**:
«Delegate to `StringBuilder` to handle everything»

Recipe:

1. Shove in `StringBuilder.append`-s
2. Let C2 to handle the rest in OptimizeStringConcat

Bottom line: Almost 1:1 to what javac currently does. This is a fallback/testing strategy: as non-intrusive as it can possibly be.

ISC, Strategies: More advanced

***_SB_SIZED**:
«*Guess the final size*, delegate to `StringBuilder`»

Recipe:

1. Call `toString()` on all reference types eagerly
2. Poll `length()` over all references, assume the max length for primitives
3. Pre-size `StringBuilder`
4. Shove in `StringBuilder.append`-s
5. Let C2 to handle the rest in OptimizeStringConcat

Bottom line: Pre-sizes SB exactly for non-primitive args.

ISC, Strategies: Even more advanced

***_SB_SIZED_EXACT**:
«*Figure out the final size*, delegate to `StringBuilder`»

Recipe:

1. Call `toString()` on *all args* eagerly
2. Poll `length()` over *all args*
3. Pre-size `StringBuilder`
4. Shove in `StringBuilder.append`-s
5. Let C2 to handle the rest in OptimizeStringConcat

Bottom line: Pre-sizes SB exactly for all args, but wastes a trip on primitives.

ISC, Strategies: Something completely different

MH_INLINE_SIZED_EXACT:
«I'm gonna build my own string concat, with private APIs and who cares?»

Recipe:

1. Call `toString()` on all reference args
2. Call `length()` *or* `T.stringSize(T t)` on everything
3. Call-and-or `coder()` on all reference args
4. Allocate `byte[]`, copy all args, convert primitives in-place
5. Invoke a private `String` constructor, handing over the array

Bottom line: OptoStringConcat benefits without OptoStringConcat mess.

ISC, Catharsis: LogLineBench

```
public class LogLineBench {
  @Param
  int size;

  String method = generateString(size);

  @Benchmark
  public String work() throws Exception {
      return "[" + System.nanoTime() + "] " +
             Thread.currentThread().getName() + ":" +
             "Calling an application method \"" + method +
             "\" without fear and prejudice.";
  }
}
```


ISC, Catharsis: Performance

	throughput, ns/op			allocated, b/op		
	1	10	100	1	10	100
9b103 -XX:-CS	132 ± 5	135 ± 4	224 ± 6	888	904	1680
BC_SB	134 ± 7	135 ± 9	220 ± 9	888	904	1680
BC_SB_SIZED	100 ± 2	99 ± 4	132 ± 7	560	592	960
BC_SB_SIZED_EXACT	73 ± 3	76 ± 2	83 ± 5	336	352	536
MH_SB_SIZED	101 ± 4	99 ± 3	135 ± 5	560	592	960
MH_SB_SIZED_EXACT	106 ± 3	109 ± 3	138 ± 4	600	632	1000
MH_INLINE_SIZED_EXACT	77 ± 3	78 ± 3	86 ± 4	288	304	488

- BC_SB dies bit does not regress: `invokedynamic` rules
- Most optimal ISC strategies do 2.6x better, and 3.4x less garbage

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Rendezvous

Rendezvous: Compact Strings + Indy String Concat

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	1	10	100	1	10	100
9b103 -XX:-CS	132 ± 5	135 ± 4	224 ± 6	888	904	1680
BC_SB	125 ± 2	126 ± 3	155 ± 4	504	512	904
BC_SB_SIZED	92 ± 5	94 ± 2	98 ± 3	312	328	512
BC_SB_SIZED_EXACT	81 ± 2	81 ± 2	83 ± 3	200	208	296
MH_SB_SIZED	88 ± 2	90 ± 1	95 ± 2	312	328	512
MH_SB_SIZED_EXACT	99 ± 1	101 ± 1	105 ± 2	344	360	536
MH_INLINE_SIZED_EXACT	75 ± 1	77 ± 1	78 ± 1	168	176	264

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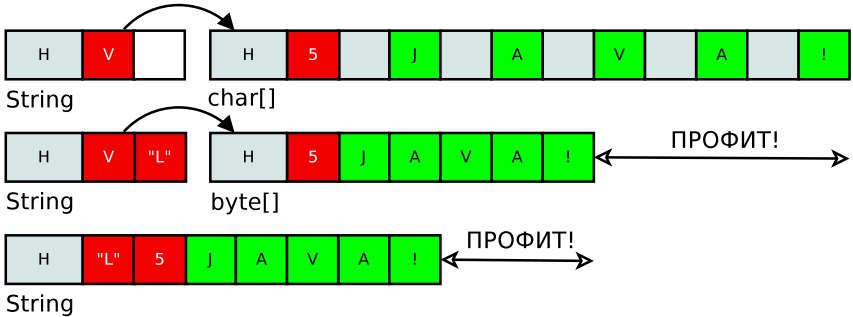
Rendezvous: String Fusion



- All is left is to throw away `byte[]`, and merge it into `String`
- String Fusion should be easier after Project Panama concludes

Rendezvous: Future

Configuration	Throughput, ns/op		Allocated, b/op
	Free[9]	Saturated[10]	
`Baseline (8u66, 9b92)`	224 ±4	1338 ±4	1680

[9] 1 mutator, 8 GC threads

[10] 8 mutators, 8 GC threads

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«Garbage Free» boundary			264
`CS + ISC (best) + String Fusion`	???	???	???
«So Much Data» boundary	???	???	235

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[10] 8 mutators, 8 GC threads

Conclusion

Conclusion: What About Real Applications?

We know it helps.on our applications **a lot**.

How much does it (help|regress) on yours? Tell us:
`https://jdk9.java.net/download/`

Conclusion: JEPs

Compact Strings:
http://openjdk.java.net/jeps/254

Indify String Concat:
http://openjdk.java.net/jeps/280

Q/A

