CASE STUDY

ONE YEAR IN ULTRA LOW LATENCY JAVA

PROJECT FOR FINANCIAL INSTITUTION

2020

ABOUT ME

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- Java Software Engineer in Sii Gdańsk.
- Trainer at infoShare Academy.

AGENDA

1. Low latency in a few words.
2. Case 1: know your API!
3. Case 2: SBE - working with bits.
4. Case 3: „will it be inlined?”.
5. Case 4: performance > „safety”.
6. Case 5: painful testing.
7. Conclusions.

LOW LATENCY IN A FEW WORDS.

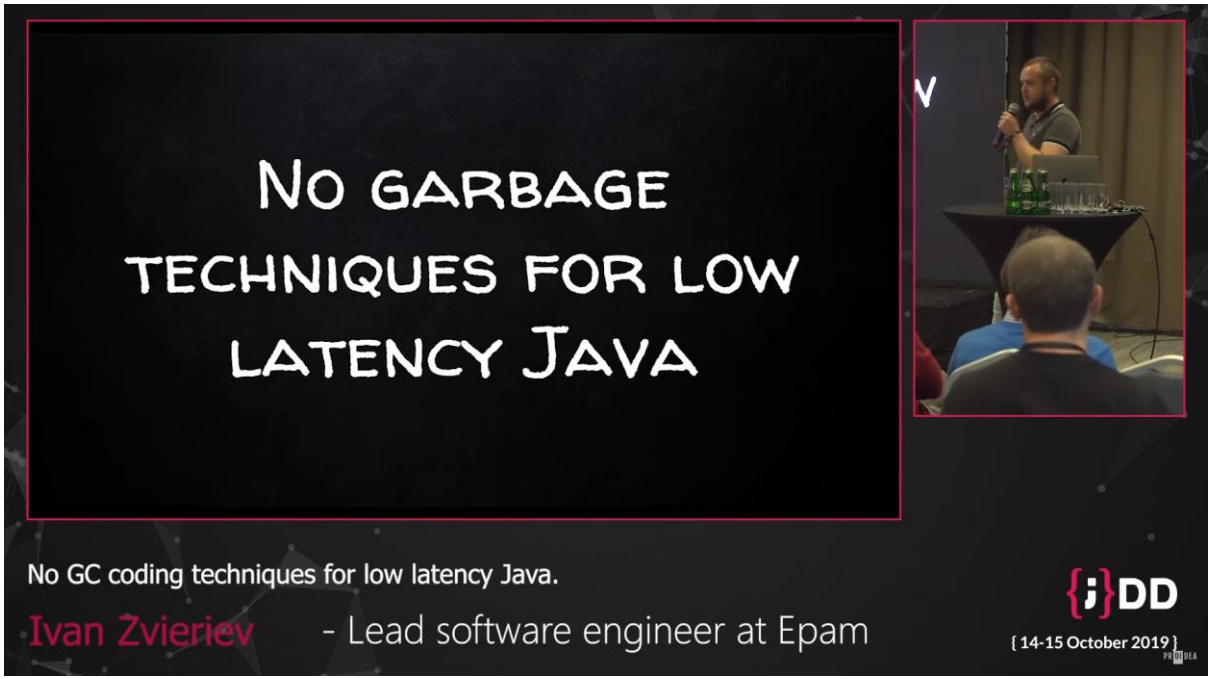
LOW LATENCY IN A FEW WORDS.

- What's low latency? – „it depends".

  „The turtle moves fast enough to hunt down a lettuce."
- Less than 1ms – ultra low latency.
- Physics matters: speed of light, cables' lengths.
- Finance domain: session layer (FIX, FIXP), encoding standard (FIX, SBE).
- Big stress and fault tolerance.
- „When the airplane crashes into the building – then we make money".
- There are ready-made tools and libraries for low latency. But...
- The fastest wins! Using ready-made tools, we are just as fast as others.

LOW LATENCY IN A FEW WORDS.

- Why Java?
- My former team colleague explained it last year on JDD 2019:



YouTube:

JDD 2019: No GC coding techniques for low latency Java, Ivan Zvieriev

LOW LATENCY IN FINANCE DOMAIN.

„A 1-millisecond advantage in trading applications can be worth **$100 million** a year to a major brokerage firm."

„[...] the physical distance between two computers processing a transaction can slow down how fast it happens. [...] To overcome it, many high-frequency algorithmic traders are moving their systems as close to the Wall Street exchanges as possible."

Source:
https://www.informationweek.com/wall-streets-quest-to-process-data-at-the-speed-of-light/d/d-id/1054287
https://en.wikipedia.org/wiki/Low_latency_(capital_markets)

INTERESTING FACTS.

[Slowing Down A Stock Exchange With 38 Miles Of Cable]

The “Magic Shoebox” – 61 km of fiber optic cable introduces a 350-microsecond delay to all trades. Source: IEX

https://hackaday.com/2019/02/26/putting-the-brakes-on-high-frequency-trading-with-physics/

https://iextrading.com/

CASE 1: KNOW YOUR API!

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- How deep is your knowledge about JDK internals?

```
List<Integer> normalList = new ArrayList<>();

List<Integer> presizedList = new ArrayList<>( initialCapacity: 1000);
```

```
public boolean add(E e) {
    modCount++;
    add(e, elementData, size);
    return true;
}
```

```
private void add(E e, Object[] elementData, int s) {
    if (s == elementData.length)
        elementData = grow();
    elementData[s] = e;
    size = s + 1;
}
```

```
private Object[] grow(int minCapacity) {
    int oldCapacity = elementData.length;
    if (oldCapacity > 0 || elementData != DEFAULTCAPACITY_EMPTY_ELEMENTDATA) {
        int newCapacity = ArraysSupport.newLength(oldCapacity,
                minGrowth: minCapacity - oldCapacity, /* minimum growth */
                prefGrowth: oldCapacity >> 1          /* preferred growth */);
        return elementData = Arrays.copyOf(elementData, newCapacity);
    } else {
        return elementData = new Object[Math.max(DEFAULT_CAPACITY, minCapacity)];
    }
```

```
@HotSpotIntrinsicCandidate
public static native void arraycopy( @NotNull() @Flow(...) Object src,  int  srcPos,
                                      @NotNull()
                                      Object dest, int destPos,
                                      int length);
```

```
* ] th… {@code src} and {@code dest} arguments refer to the
* s ne array object, then the copying is performed as if the
* c mponents at positions {@code srcPos} through
* {@code srcPos+length-1} were first copied to a temporary
* array with {@code length} components and then the contents of
* the temporary array were copied into positions
* {@code destPos} through {@code destPos+length-1} of the
* destination array.
```

CASE 1: KNOW YOUR API!

- How often do you investigate native method's implementation?

[...]

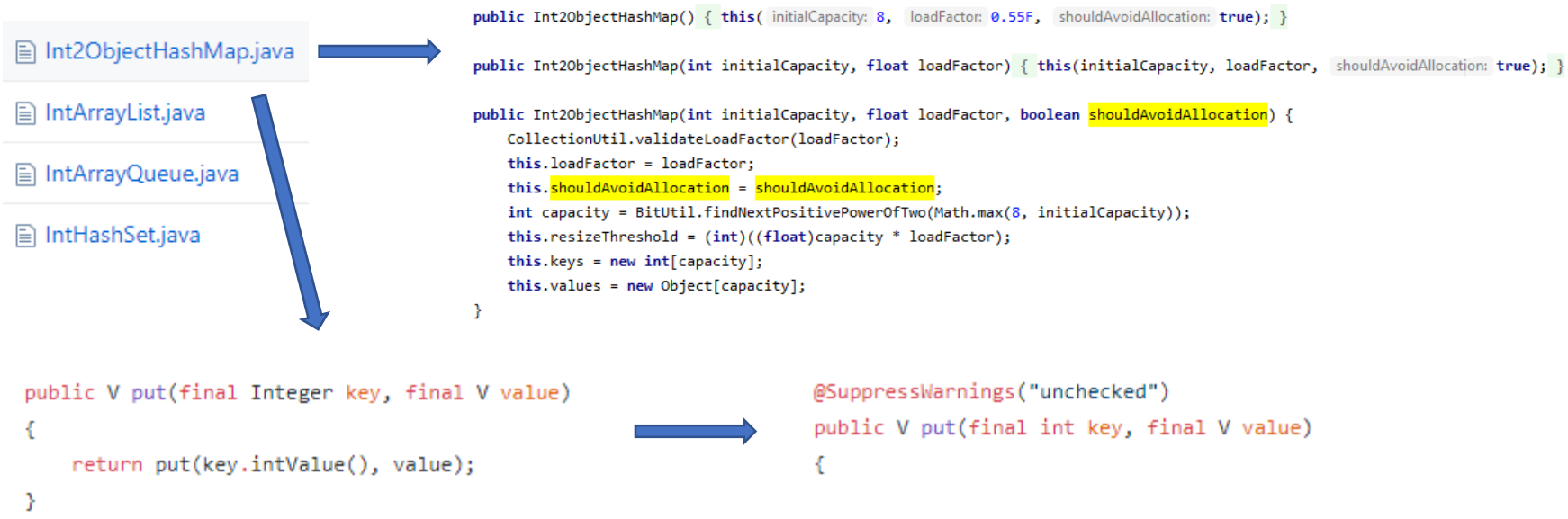
```
248 void ObjArrayKlass::copy_array(arrayOop s, int src_pos, arrayOop d,
249                                  int dst_pos, int length, TRAPS) {
250   assert(s->is_objArray(), "must be obj array");
251
252   if (!d->is_objArray()) {
253     ResourceMark rm(THREAD);
254     stringStream ss;
255     if (d->is_typeArray()) {
256       ss.print("arraycopy: type mismatch: can not copy object array[] into %s[]",
257                type2name_tab[ArrayKlass::cast(d->klass())->element_type()]);
258     } else {
259       ss.print("arraycopy: destination type %s is not an array", d->klass()->external_name());
260     }
261     THROW_MSG(vmSymbols::java_lang_ArrayStoreException(), ss.as_string());
262   }
263
```

[...]

Source: http://hg.openjdk.java.net/jdk/jdk14/file/6c954123ee8d/src/hotspot/share/oops/objArrayKlass.cpp

CASE 1: KNOW YOUR API!

- Agrona from https://real-logic.co.uk/
  - https://github.com/real-logic/agrona/tree/master/agrona/src/main/java/org/agrona/collections



CASE 2: SBE – WORKING WITH BITS.

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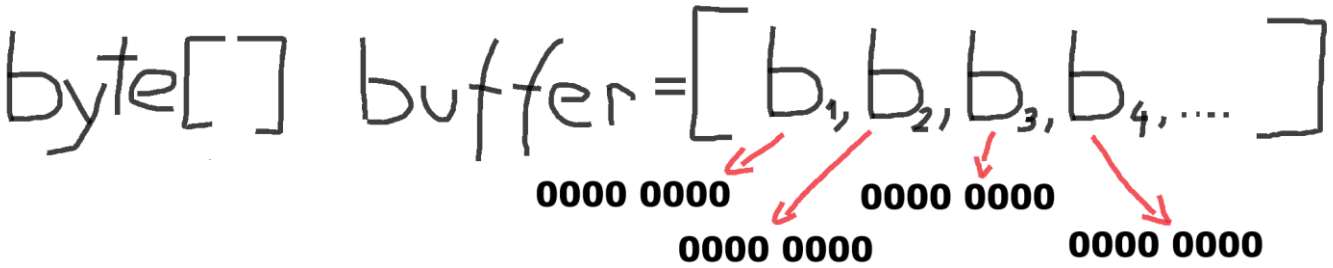
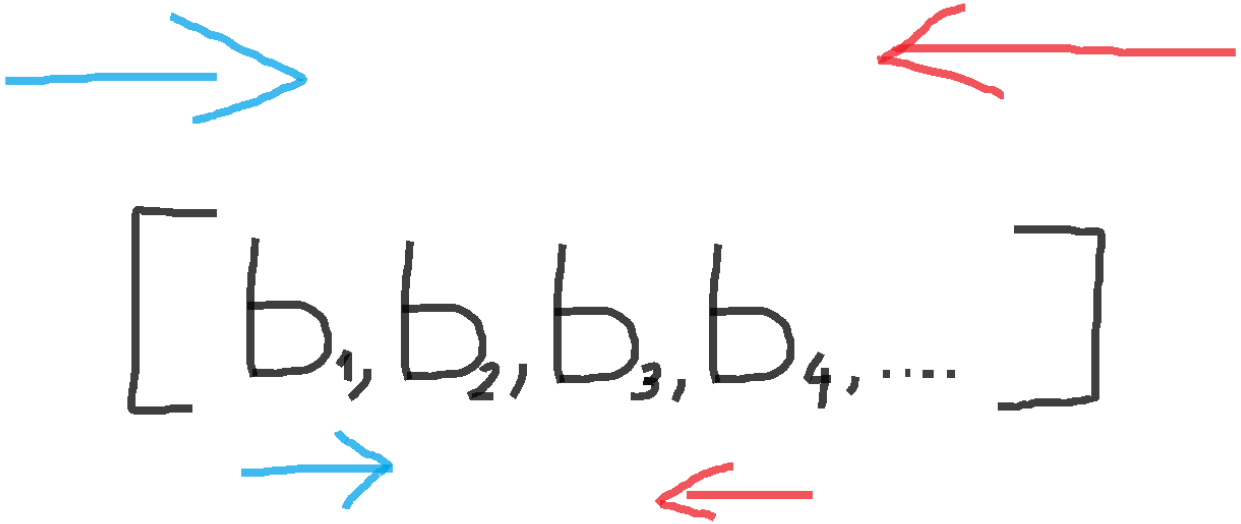
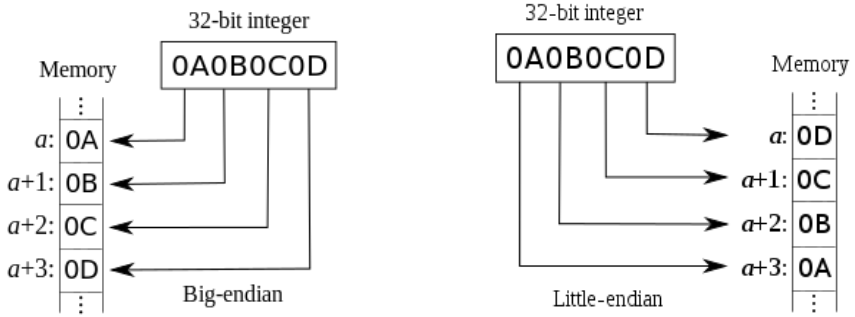
- Simple Binary Encoding (SBE).



CASE 2: SBE – WORKING WITH BITS.

0010 0001 0001 1101 0001 1010 1110 0011





Source: https://en.wikipedia.org/wiki/Endianness

CASE 2: SBE – WORKING WITH BITS.

```java
/**
 * A typesafe enumeration for byte orders.
 *
 * @author Mark Reinhold
 * @author JSR-51 Expert Group
 * @since 1.4
 */

public final class ByteOrder {

    private String name;

    private ByteOrder(String name) { this.name = name; }

    public static final ByteOrder BIG_ENDIAN
        = new ByteOrder( name: "BIG_ENDIAN");

    public static final ByteOrder LITTLE_ENDIAN
        = new ByteOrder( name: "LITTLE_ENDIAN");

    private static final ByteOrder NATIVE_ORDER
        = Unsafe.getUnsafe().isBigEndian()
            ? ByteOrder.BIG_ENDIAN : ByteOrder.LITTLE_ENDIAN;
```

CASE 2: SBE – WORKING WITH BITS.

int – 4 bajty – 32 bity

-2 147 483 648 ≤ int ≤ 2 147 483 647

Integer.MIN_VALUE

Integer.MAX_VALUE

```
System.out.println("Binary representation of Integer.MIN_VALUE: " +
        Integer.toBinaryString(Integer.MIN_VALUE));
```

```
System.out.println("Binary representation of Integer.MAX_VALUE: " +
        Integer.toBinaryString(Integer.MAX_VALUE));
```

1000 0000 0000 0000 0000 0000 0000 0000

0111 1111 1111 1111 1111 1111 1111 1111

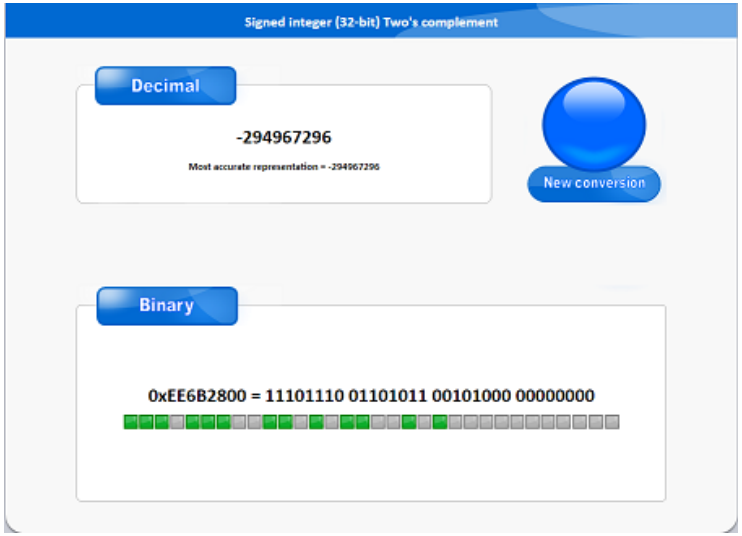
CASE 2: SBE – WORKING WITH BITS.

4 000 000 000 -> ile bitów?

```
System.out.println("Binary representation of 4 000 000 000: "
        + Long.toBinaryString( i: 4_000_000_000L));
```

1110 1110 0110 1011 0010 1000 0000 0000

0000 0000 0000 0000 0000 0000 0000 0000 1110 1110 0110 1011 0010 1000 0000 0000



Source: https://www.binaryconvert.com/result_signed_int.html?hexadecimal=EE6B2800

CASE 2: SBE – WORKING WITH BITS.

```
System.out.println("Binary representation of -294 967 296: " +
        Integer.toBinaryString( i: -294_967_296));

System.out.println(Long.toBinaryString( i: 4_000_000_000L).equals(Integer.toBinaryString( i: -294_967_296)));
```

Result of 'Long.toBinaryString(4_000_000_000L).equals(Integer.toBinaryString(-294_967_296))' is always 'true'

f

1111

&

binary AND operator

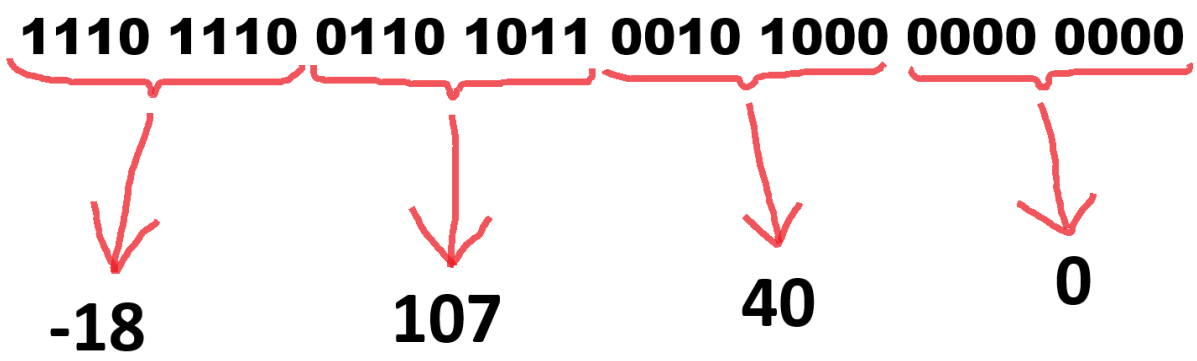
```
System.out.println("UnsignedInt value of (-294 967 296) as Java long: " + Integer.toUnsignedLong( x: -294967296));
System.out.println("UnsignedInt value of (-294 967 296) as Java long: " + ((-294967296) & 0xffffffffL));
```

```
UnsignedInt value of (-294 967 296) as Java long: 4000000000
UnsignedInt value of (-294 967 296) as Java long: 4000000000
```

CASE 2: SBE – WORKING WITH BITS.

$$-128 \leq \text{byte} \leq 127$$

Byte.MIN_VALUE Byte.MAX_VALUE



CASE 2: SBE – WORKING WITH BITS.

byte[] buffer = [**-18, 107, 40, 0** , ...]

ASCII codes

(character codes)

40 – (

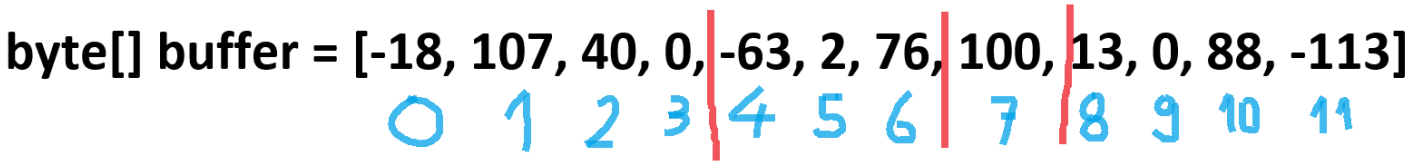
...

65 – A

...

122 – z

CASE 2: SBE – WORKING WITH BITS.



Specification: message_1

Big endian

offset = 0, length = 4 -> price

offset = 4, length = 3 -> buyer ID

offset = 7, length = 1 -> currency symbol

offset = 8, length = 4 -> finance instrument

buffer size = 12

CASE 3: „WILL IT BE INLINED?”.

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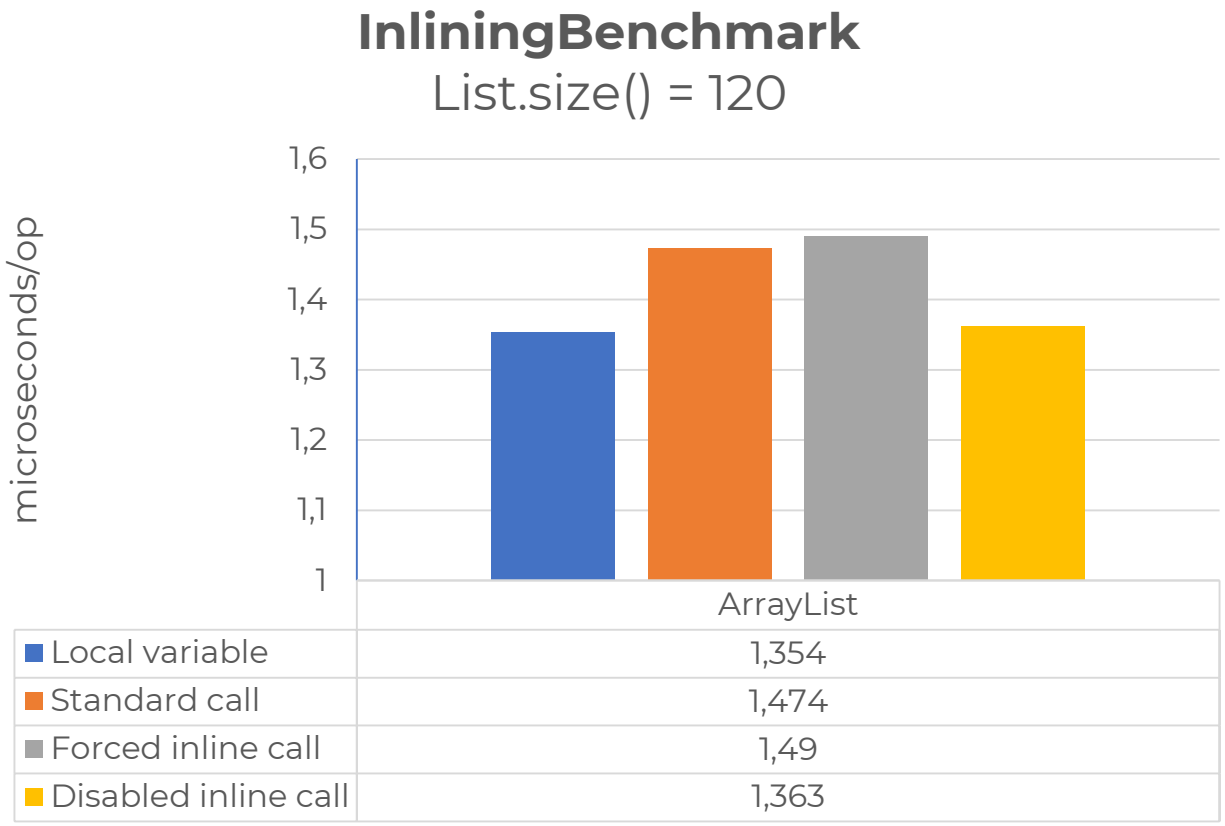
```java
//1st case
int listSize = list.size();
for (int i = 0; i < listSize; i++) {
    mapOne.put(i, listSize );
}

//2nd case
for (int i = 0; i < list.size(); i++) {
    mapTwo.put(i, list.size());
}
```

CASE 3: „WILL IT BE INLINED?”.

- What’s faster? Will it be inlined? Which solution is better?
- Small Pull Request – around 30 lines of code.
- 5 days of debating in Code review.
- Email corespondence:
  - couple of people CC,
  - sending Java code via email – „benchmark in main”,
  - stacktrace from compilation,
  - JMH benchmarks.

CASE 3: „WILL IT BE INLINED?”.



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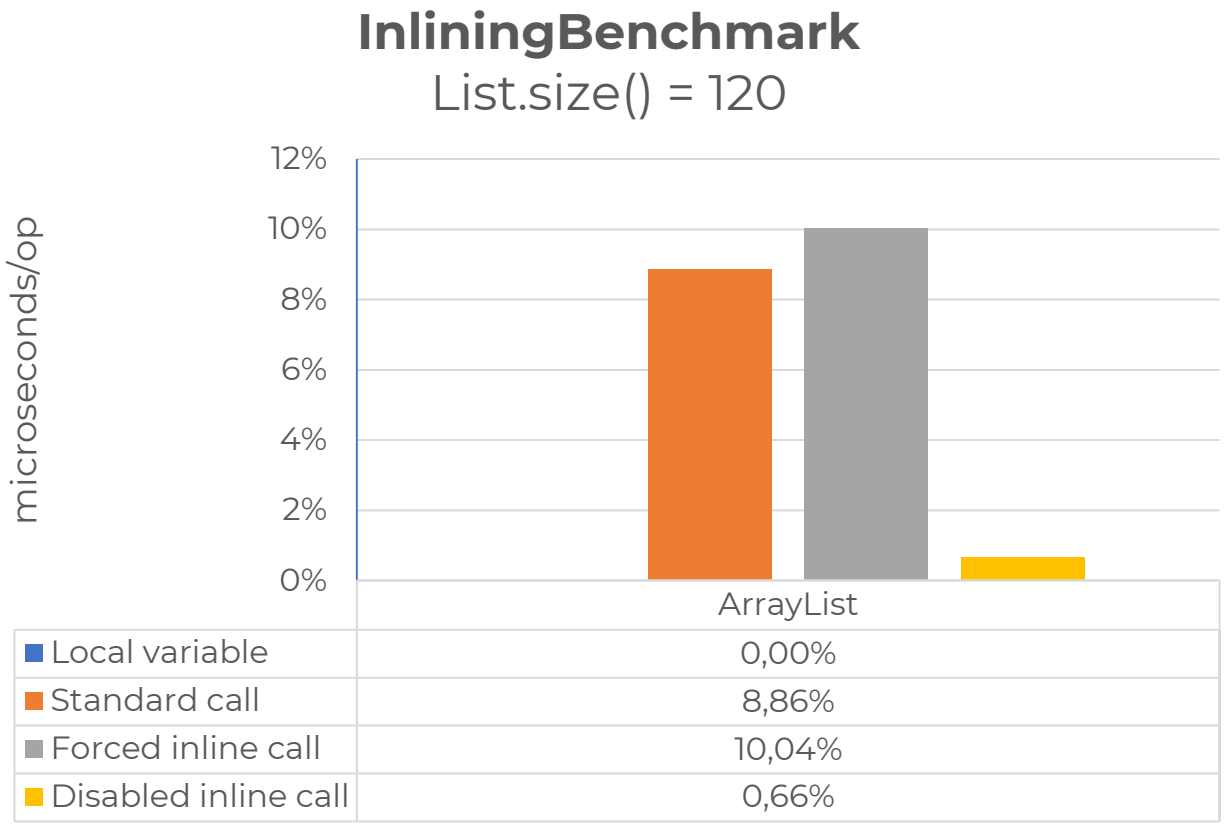

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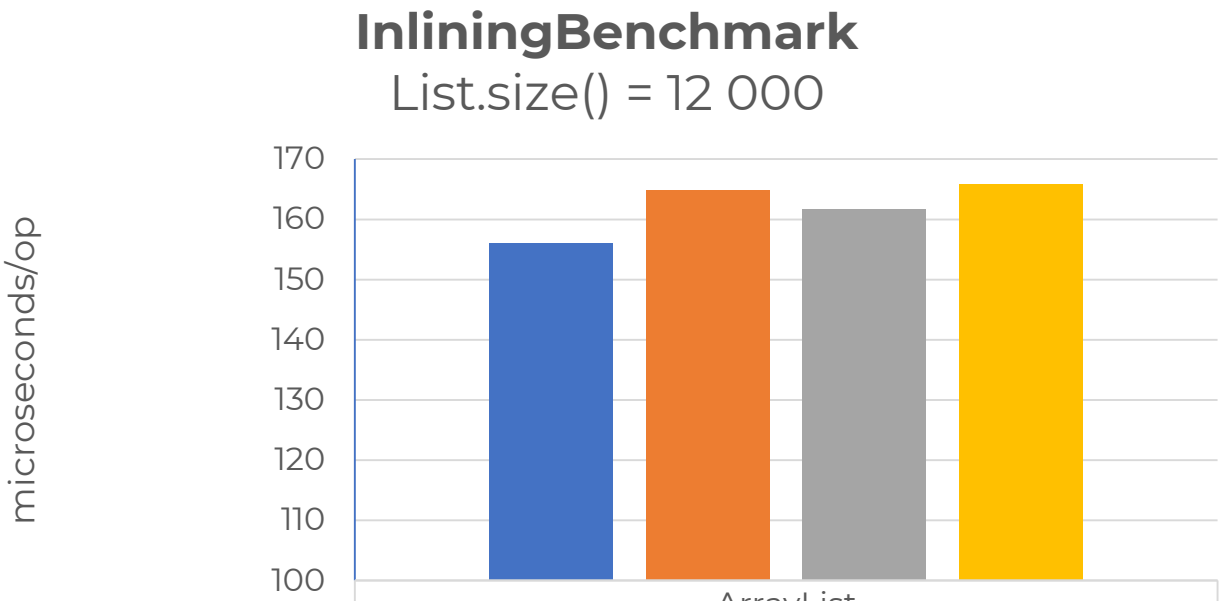
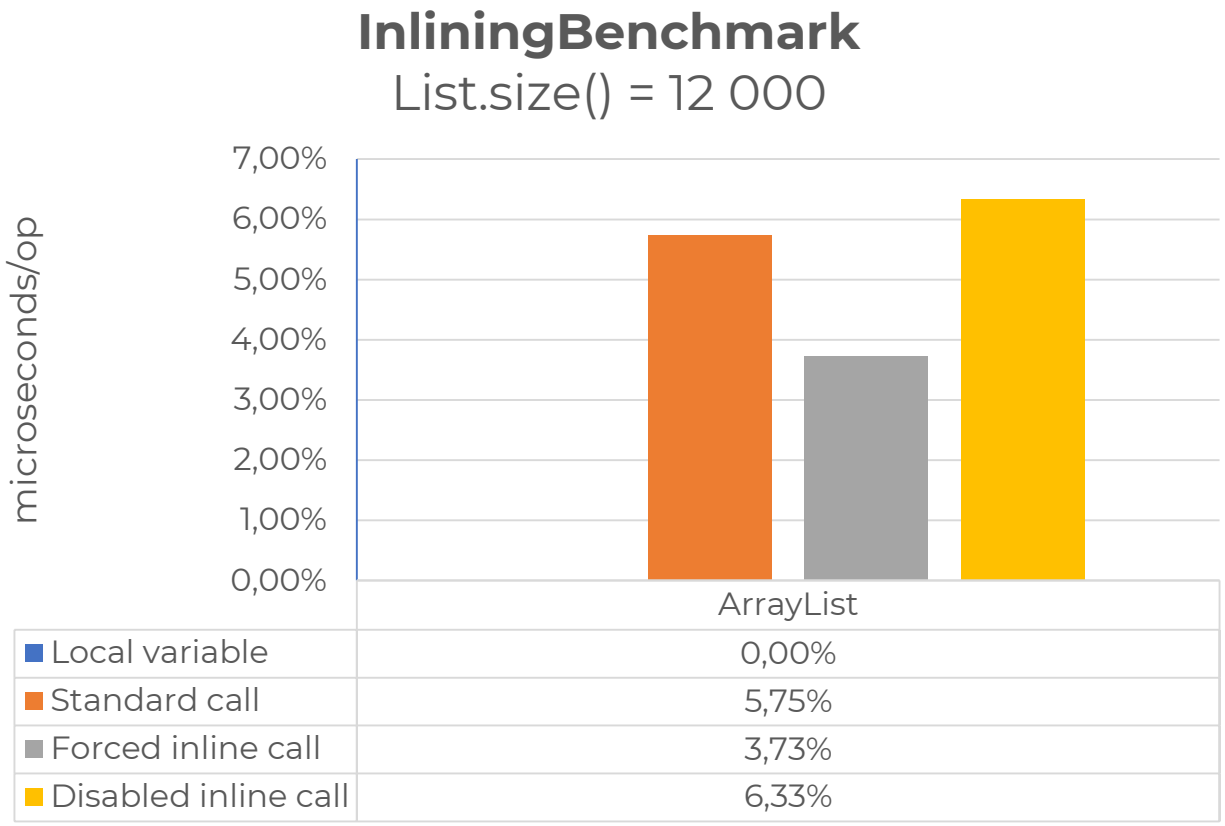


	ArrayList
Local variable	155,975
Standard call	164,938
Forced inline call	161,789
Disabled inline call	165,851

CASE 3: „WILL IT BE INLINED?”.



CASE 3: „WILL IT BE INLINED?”.

- Conclusion?
- **THINK REASONABLE!**
- Waste of resources: time, money, health...
- Result?

```
int listSize = list.size();
for (int i = 0; i < listSize; i++) {
```

and....

STFU!!!

CASE 4: PERFORMANCE > „SAFETY”.

CASE 4: PERFORMANCE > „SAFETY”.

- Some problems come from the codding approach.
  - Performance > „safety”.
  - Run -> POSITIVE
  - Debug -> NEGATIVE

CASE 5: PAINFUL TESTING.

CASE 5: PAINFUL TESTING.

- What happens when you:
  - reuse and reset some objects,
  - but maintain state of others,
  - in multithreaded application?
- Tests can become undeterministic...

CONCLUSIONS.

CONCLUSIONS.

- Very demanding work.
- Sophisticated problems.
- A lot to learn.
- Big possibility of growth.
- Easy to get frustrated.
- Easy to get bored.
- You will get some good and bad coding practices.
- Not for everyone!
- „Team-fit” for that kind of project:
  - Tell briefly about the project to the candidate.
  - Ask the most important question: „do you want to do this?”.
  - And then assess necessary knowledge.

THANKS!

QUESTIONS?