Neil Masson – Java L3 Service Core Teamt
24th September 2013

New JVM Features – Multitenancy and Packed Objects

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Introduction to the speaker

- Neil Masson

- Many (many) years experience in Java
- IBM Service – Core L3 Team

What should you get from this talk?

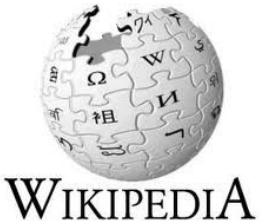
- JVM proving to be a fertile ecosystem for languages
- Plenty of opportunity to innovate in other spaces
- Runtime is the gateway to this innovation
- Largely ignored the last few years, but this is where the core inventions can occur

The runtime **isn’t** boring!

Multitenancy

Just what do you mean by “multitenancy”?

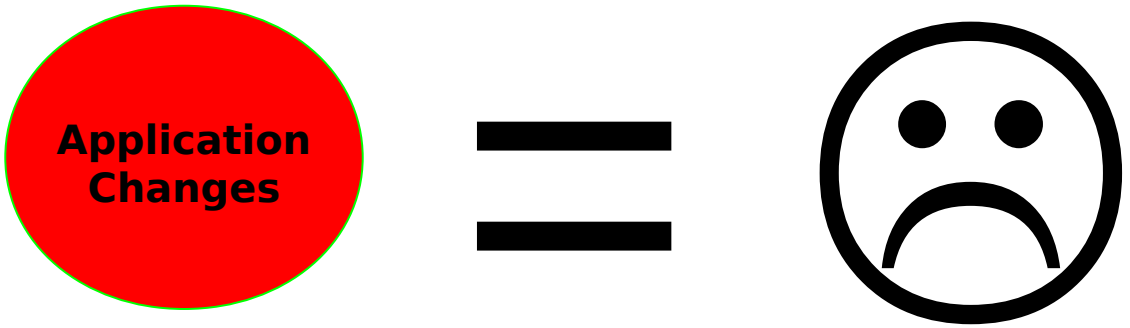
With a multitenant architecture, a software application is designed to virtually partition its data and configuration, and each client organization works with a customized virtual application instance.



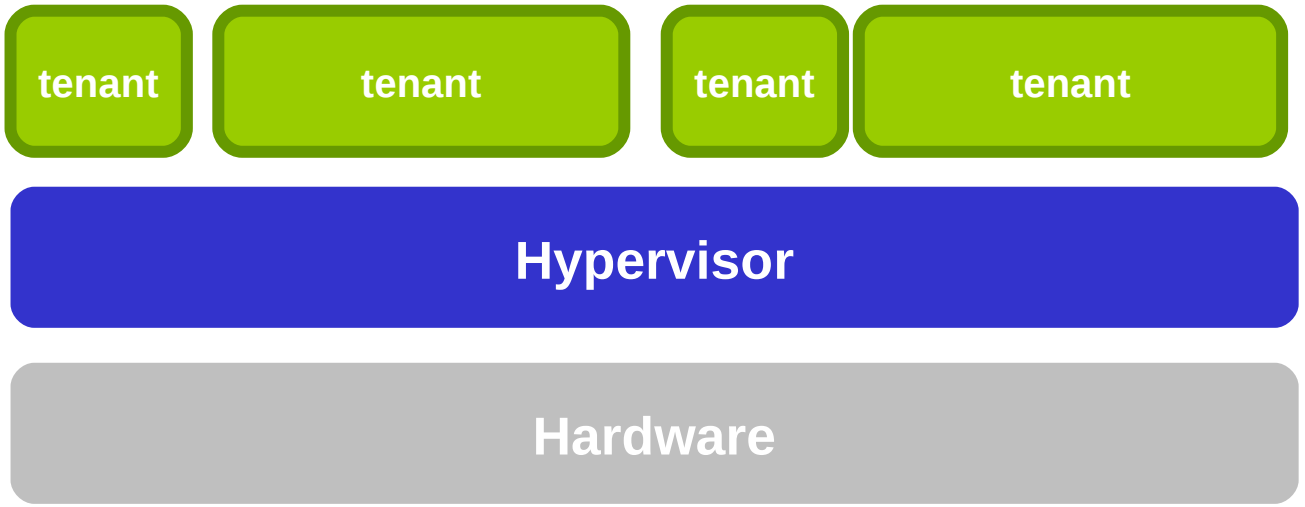
- **Working Definition**
  - A single instance of a software application that serves multiple customers
    → Each customer is a tenant.
  - Tenants can customize some parts of the application (look and feel) but not the code.
  - Infrastructure usually opaque
    → opportunity for provider

Why? Cost Savings: As compared to single-tenant deployment model

JDK Support for Spectrum of Sharing / Multitenancy (Level 1-5)

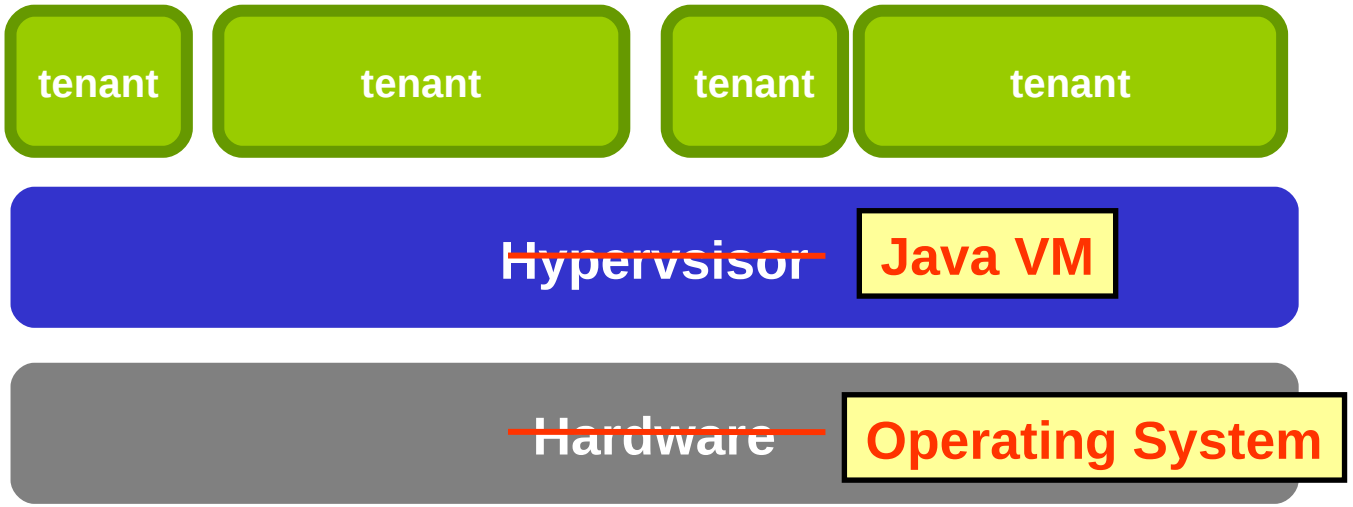


Hardware Virtualization



- Hypervisors run multiple applications side-by-side safely
- Advantages
  - Capture idle CPU cycles
  - Automatic de-duplication (RAM)
  - Ability to meter and shift resource toward demand
  - No need to change tenant applications

Hardware Virtualization

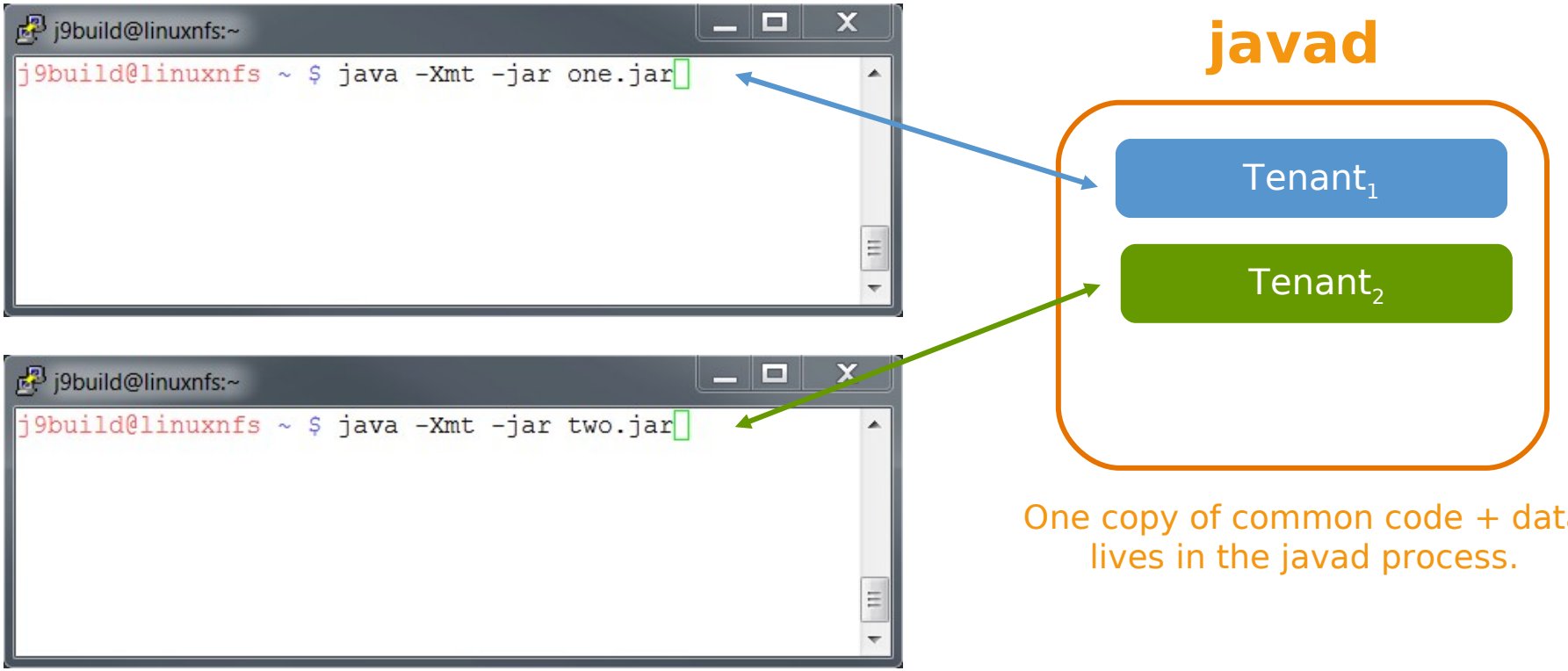


- ~~Hypervisors~~ JVMs can run multiple applications side-by-side safely
- Advantages
  - Capture idle CPU cycles
  - Automatic de-duplication (ability to share Java artifacts)
  - Ability to meter and shift resource toward demand
  - No need to change tenant applications

Multitenancy: Low (or no) barrier to entry

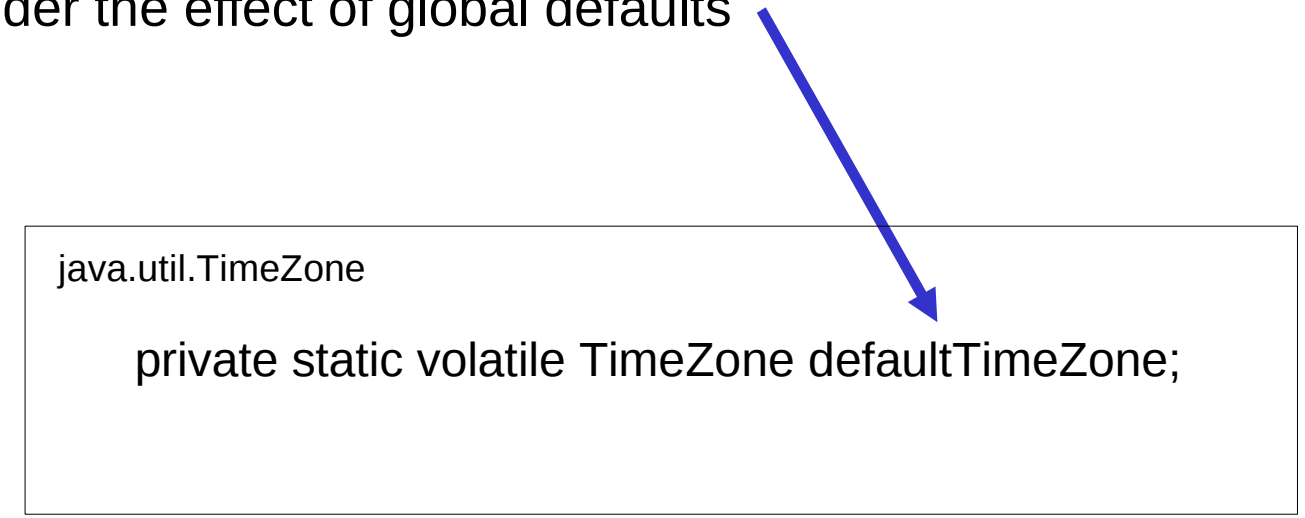
- Multitenancy is all about reducing duplication by transparently sharing a JVM
  - 1 GC, 1 JIT, shared heap objects
  - plus: JVM-enforced resource constraints to meter and limit consumption

- Ergonomics: Opt-in to multitenancy with a single flag: -Xmt (multitenancy)
  - no application changes required



JVM: Separating State

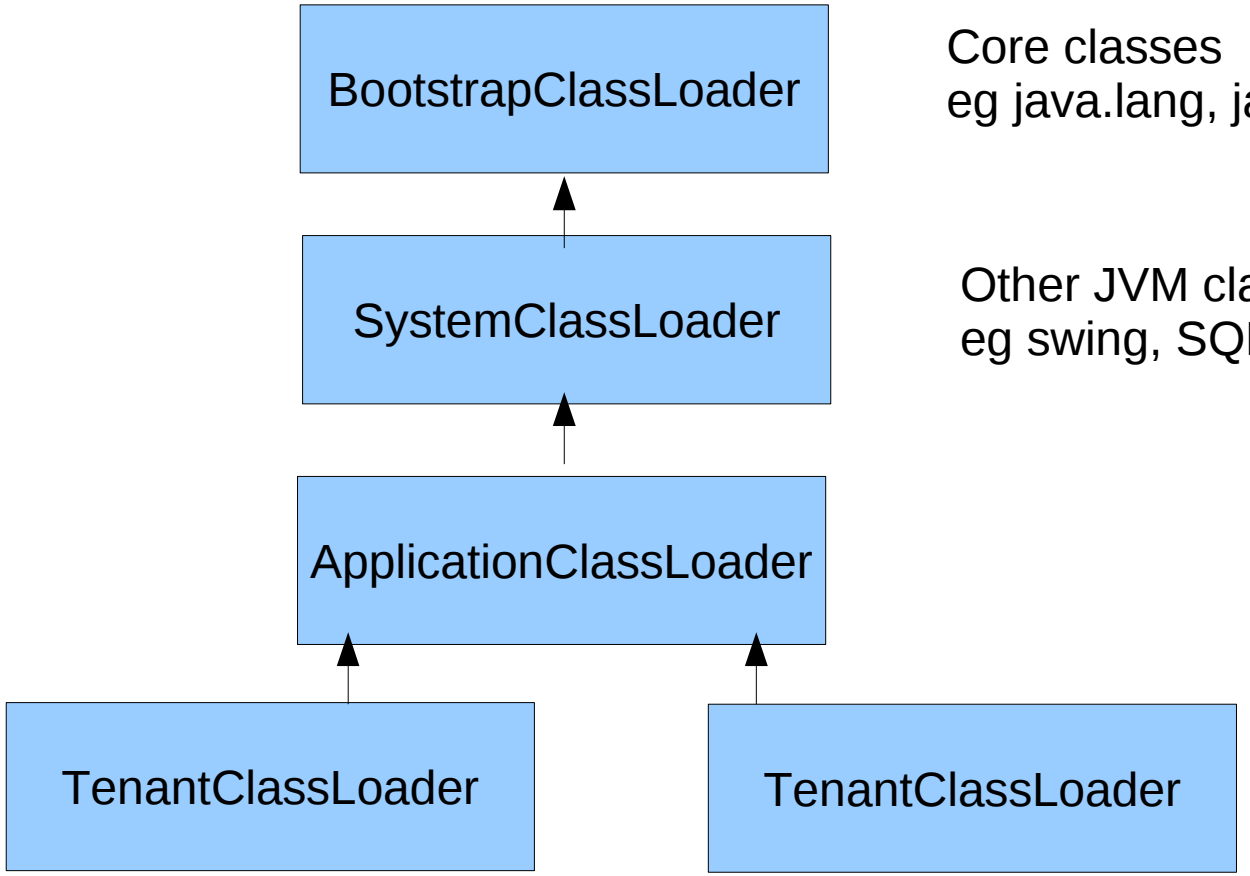
- Static variables are a problem for sharing
- Consider the effect of global defaults



JVM: Separating State

- Use @TenantScope annotation
- Each tenant has its own version of defaultTimeZone
- All JVM classes annotated

Tenants: Separating State

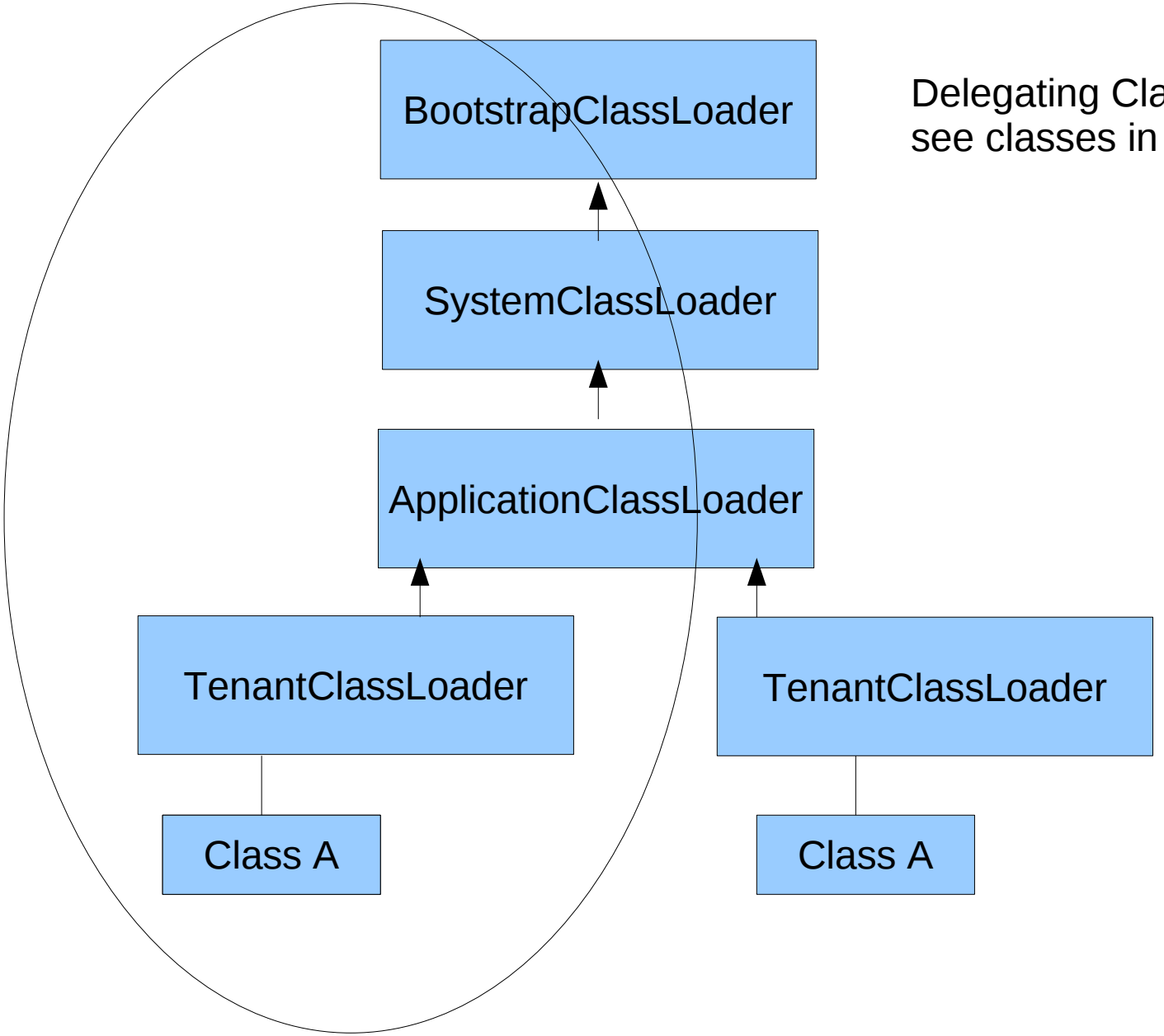


Core classes
eg java.lang, java.util, ...

Other JVM classes
eg swing, SQL, ...

ClassPath

Tenants: Separating State



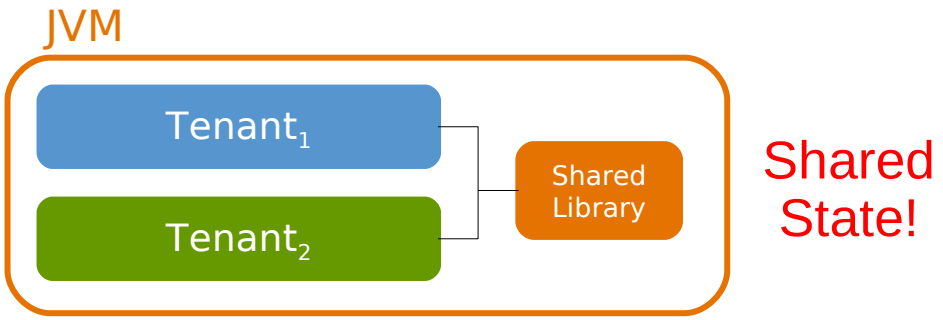
Delegating ClassLoaders only
see classes in their parent Classloaders

Class A != Class A

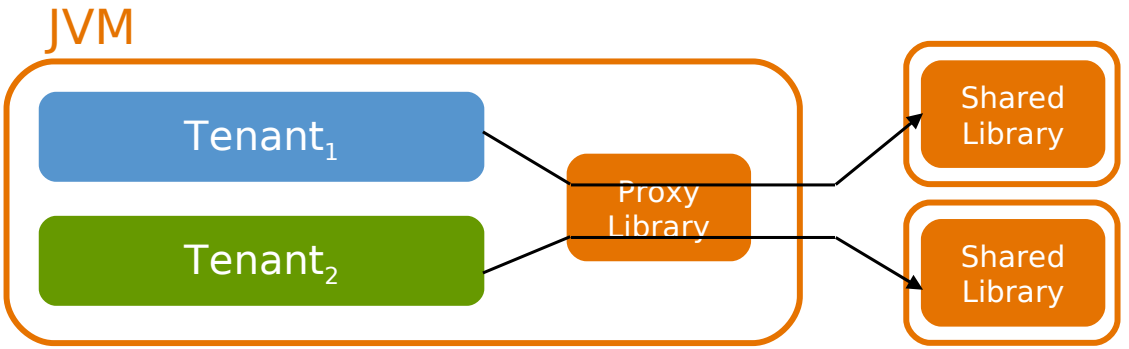
More that just JVM State…

- Throttling of resources
  - Threads, GC, sockets, files (IO in general), native memory
- Past and existing examples do exist!
  - Commercial / In house custom solutions
  - JSR 181 Isolates / 284 Resource Management
- Security is of course huge

Other Thoughts – Native Libraries and shared state



- Native libraries contain state that may not be shareable across tenants



- Use separate processes to manage different state
- Each process now holds the context
- Challenges: Latency

Questions?

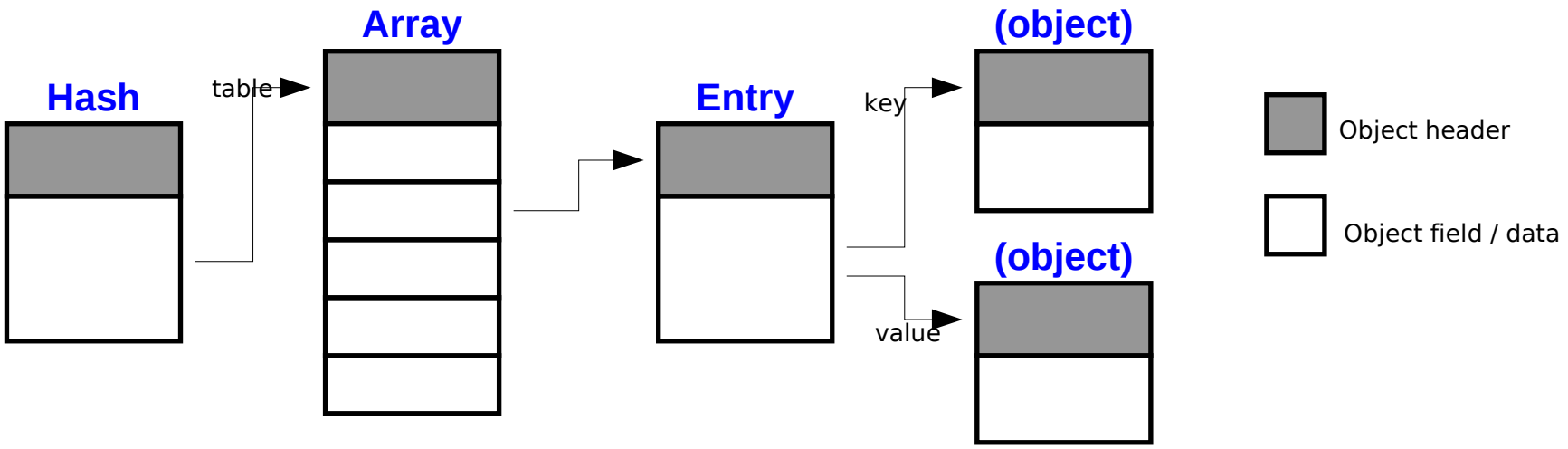
Packed Objects

Problem? What problem?

- JNI just isn't a great way to marshal data
- Locality in Java can matter
- Existing native and data placement stories aren't very good
- In many cases, legacy systems exist – the interop is just terrible

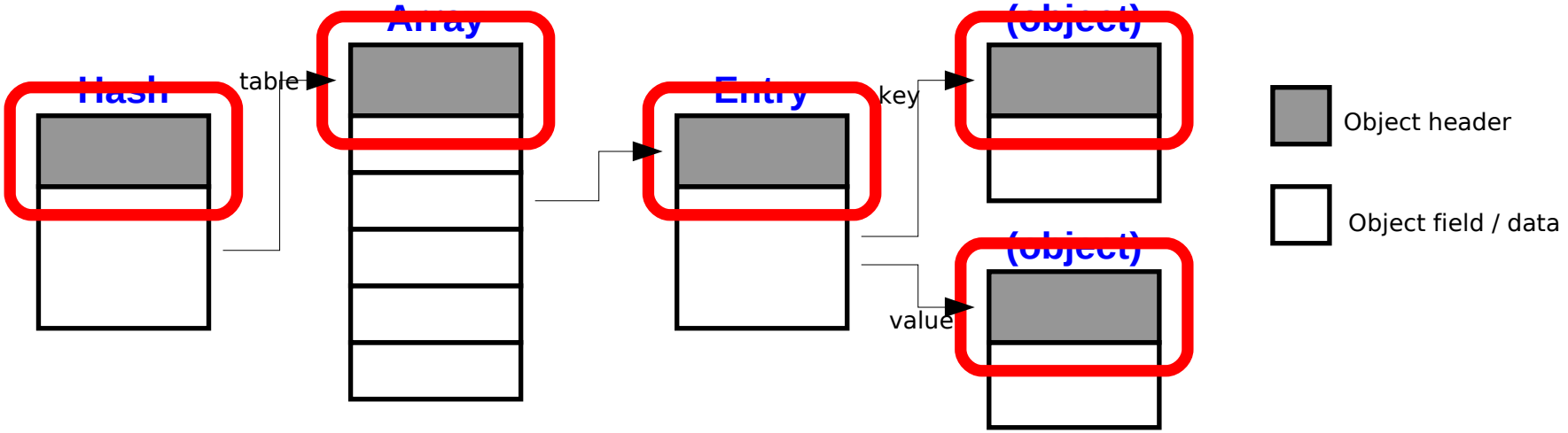
- So we want something that integrates well with the Java language and helps us…

What are we trying to solve?



Simple enough…

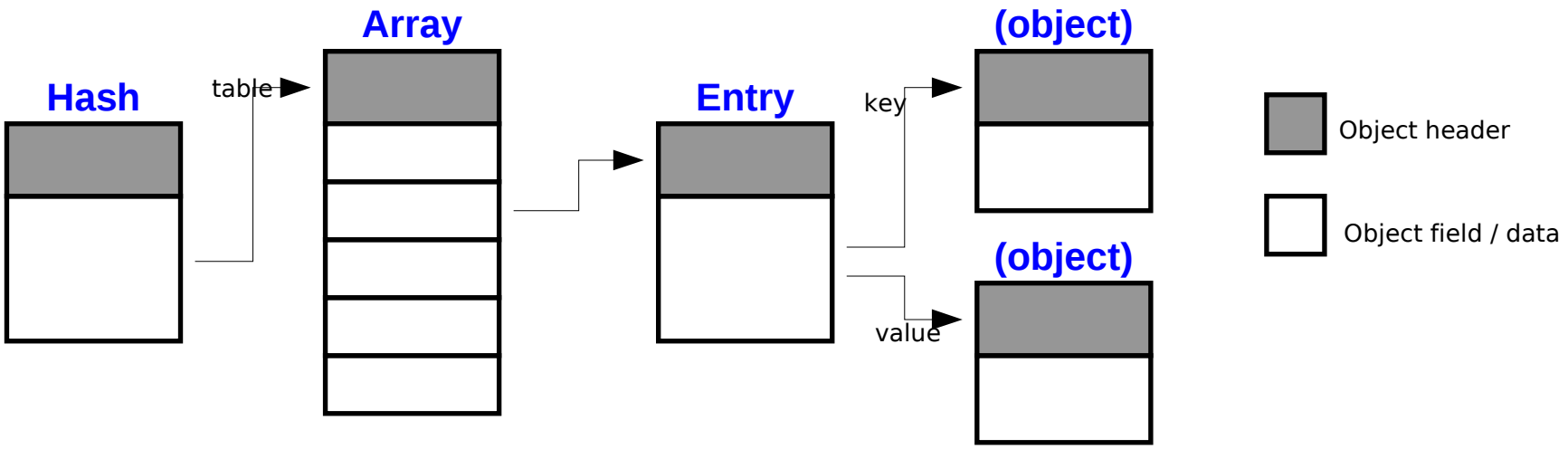
What are we trying to solve?



Simple enough…

- Header overhead

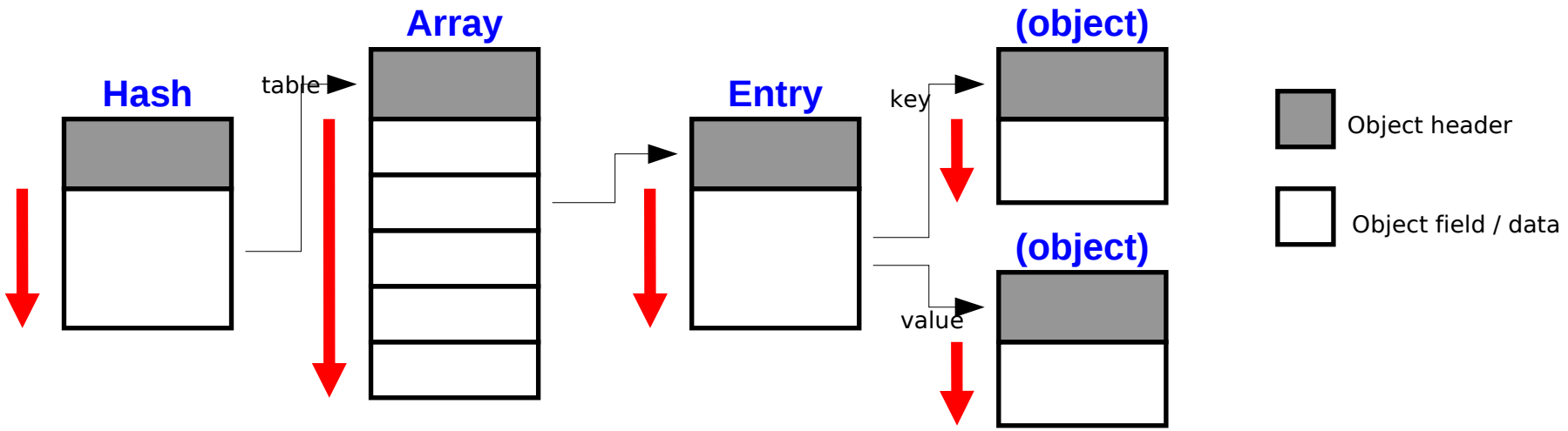
What are we trying to solve?



Simple enough…

- Header overhead
- Pointer chasing

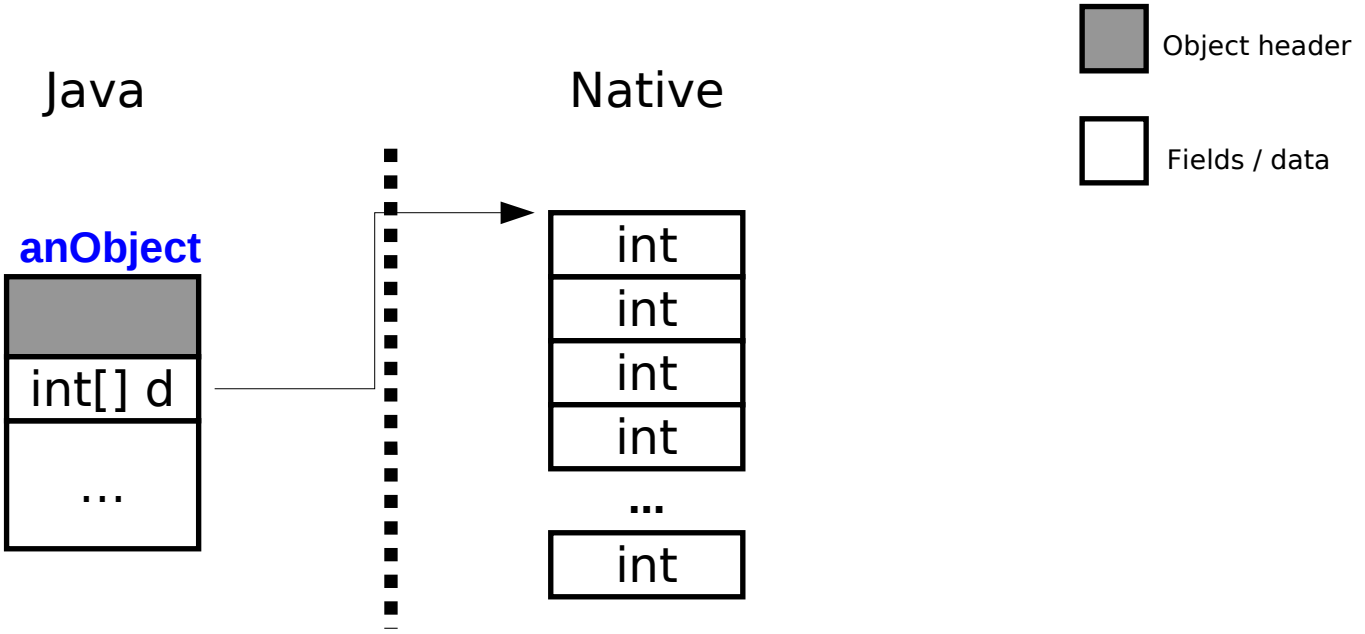
What are we trying to solve?



Simple enough…

- Header overhead
- Pointer chasing
- Locality

What are we trying to solve?



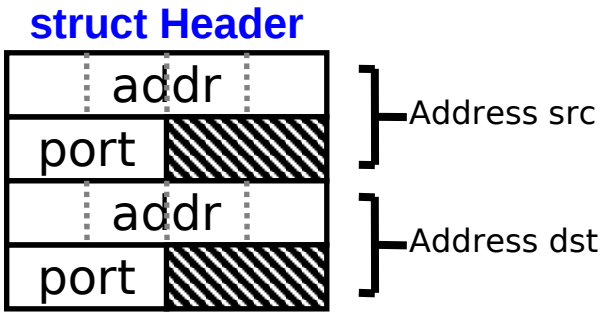
Fighting the Java/Native interface

Ok so we have some criteria…

- Ability to do away with headers
- Ability to bring multiple objects close together
- On heap / off heap seamless referencing of data

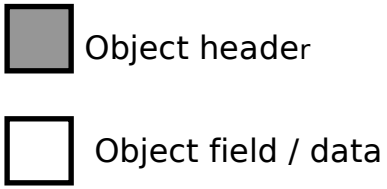
- This actually sounds a lot like C structure types

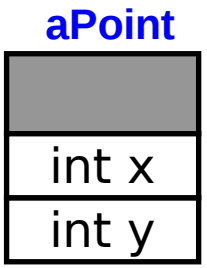
```
struct Address {
  char[4] addr;
  short port;
}
struct Header {
  struct Address src;
  struct Address dst;
}
```



- Packed Objects!

Packed Objects: Under the covers





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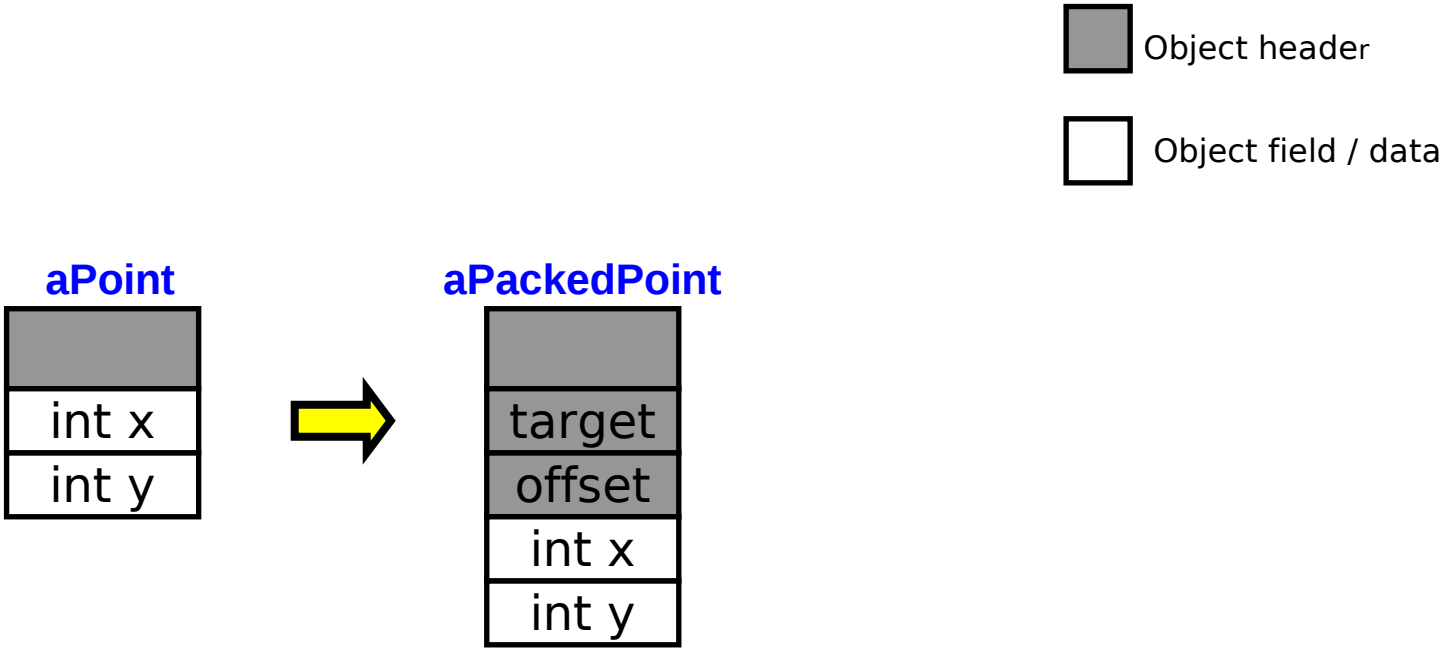
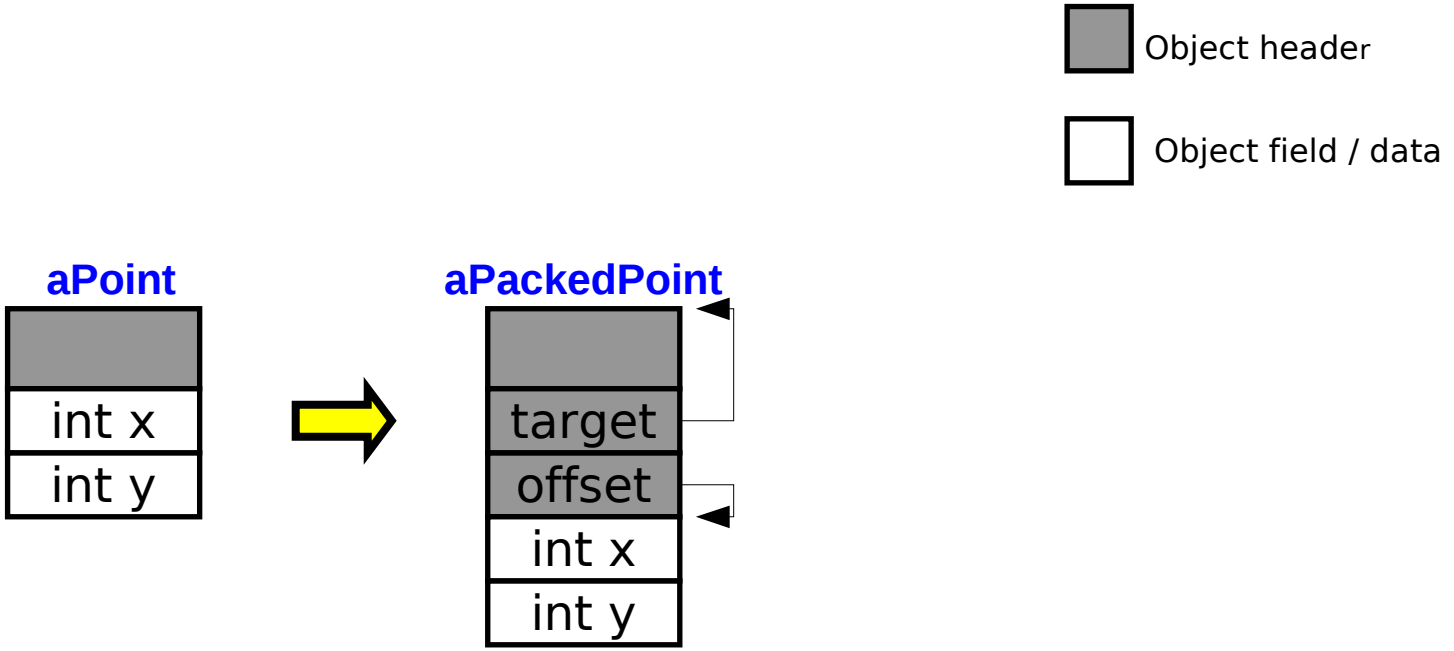


Packed Objects: Under the covers



Packed Objects: In Practice

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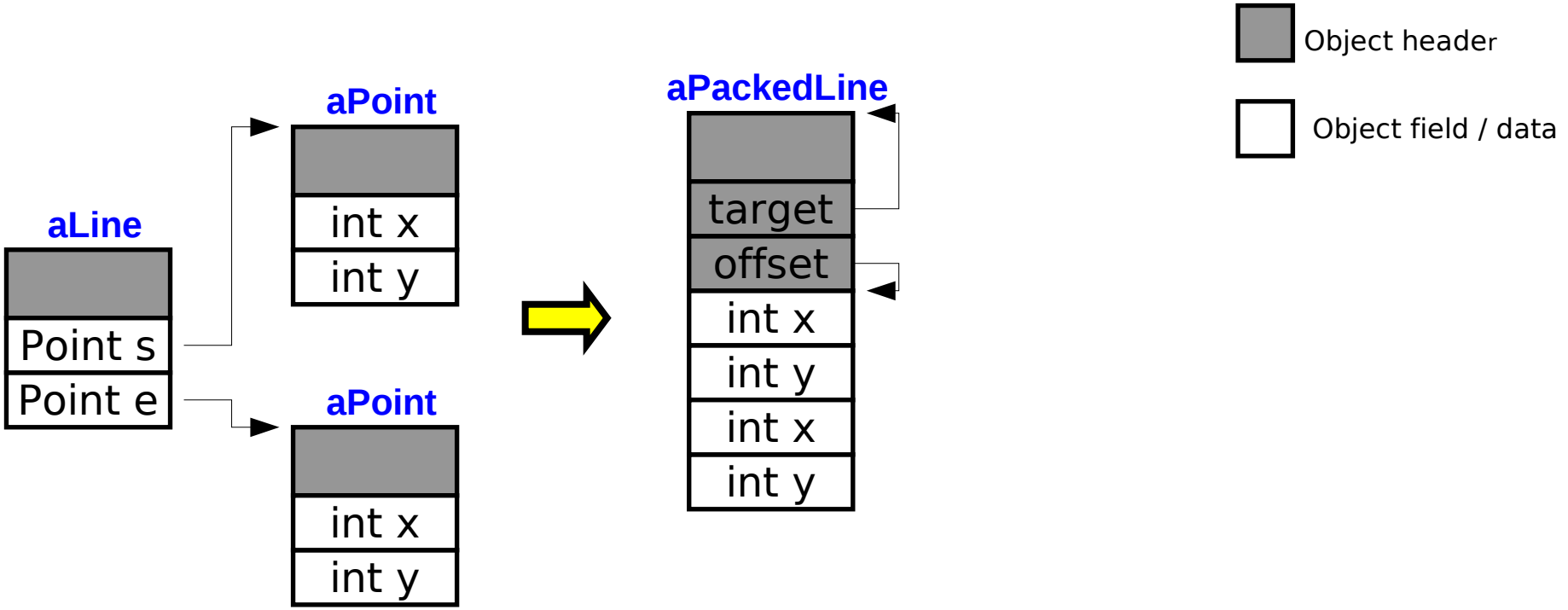
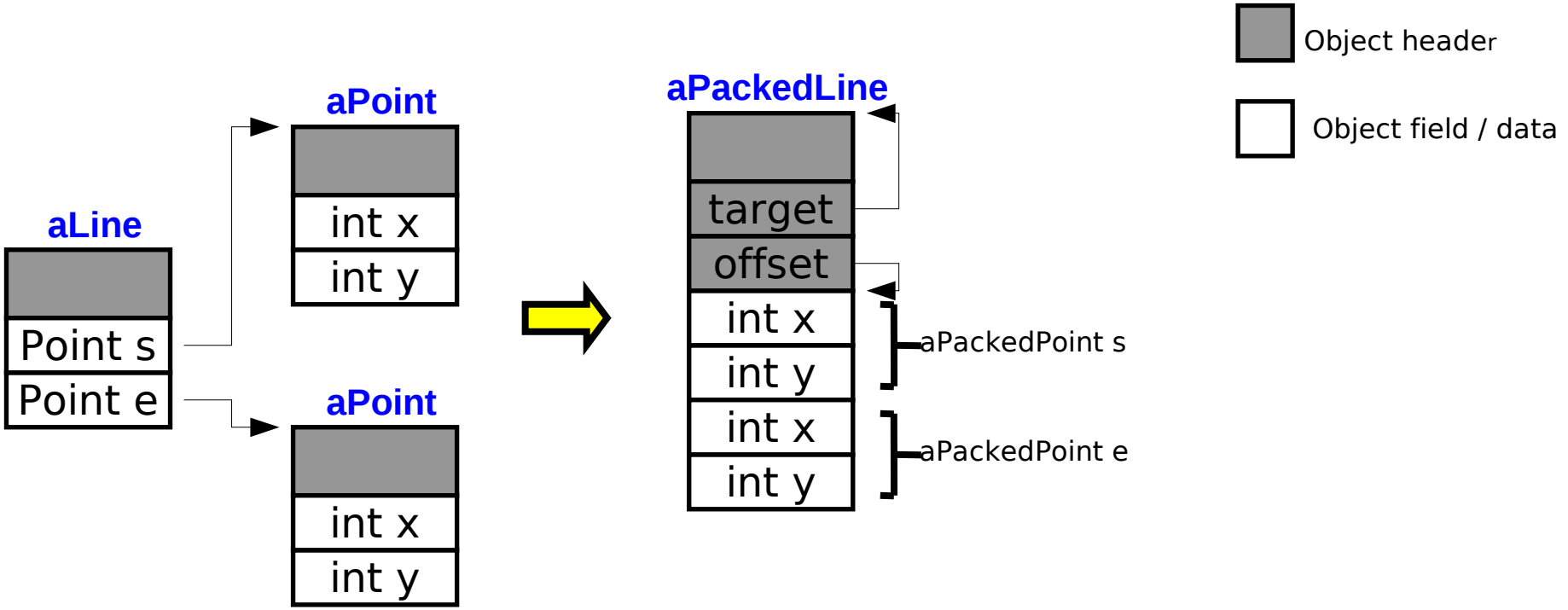


Packed Objects: In Practice



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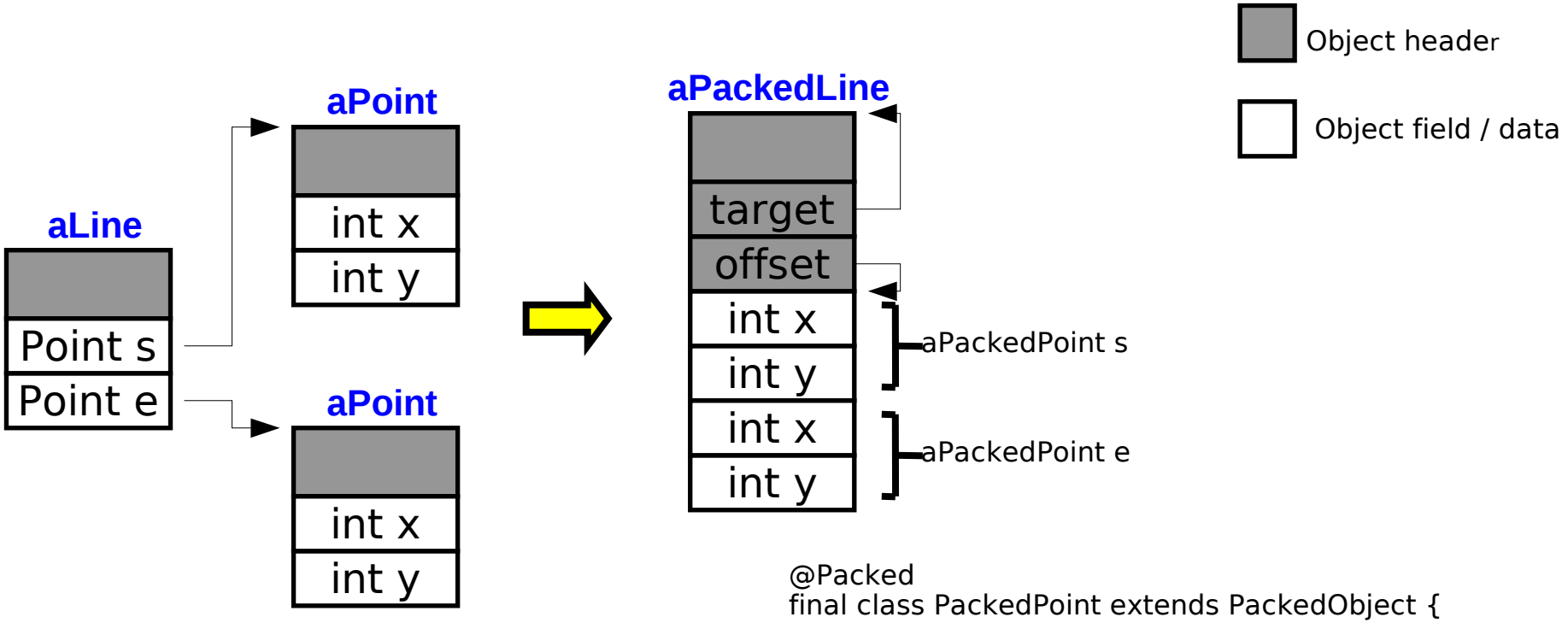
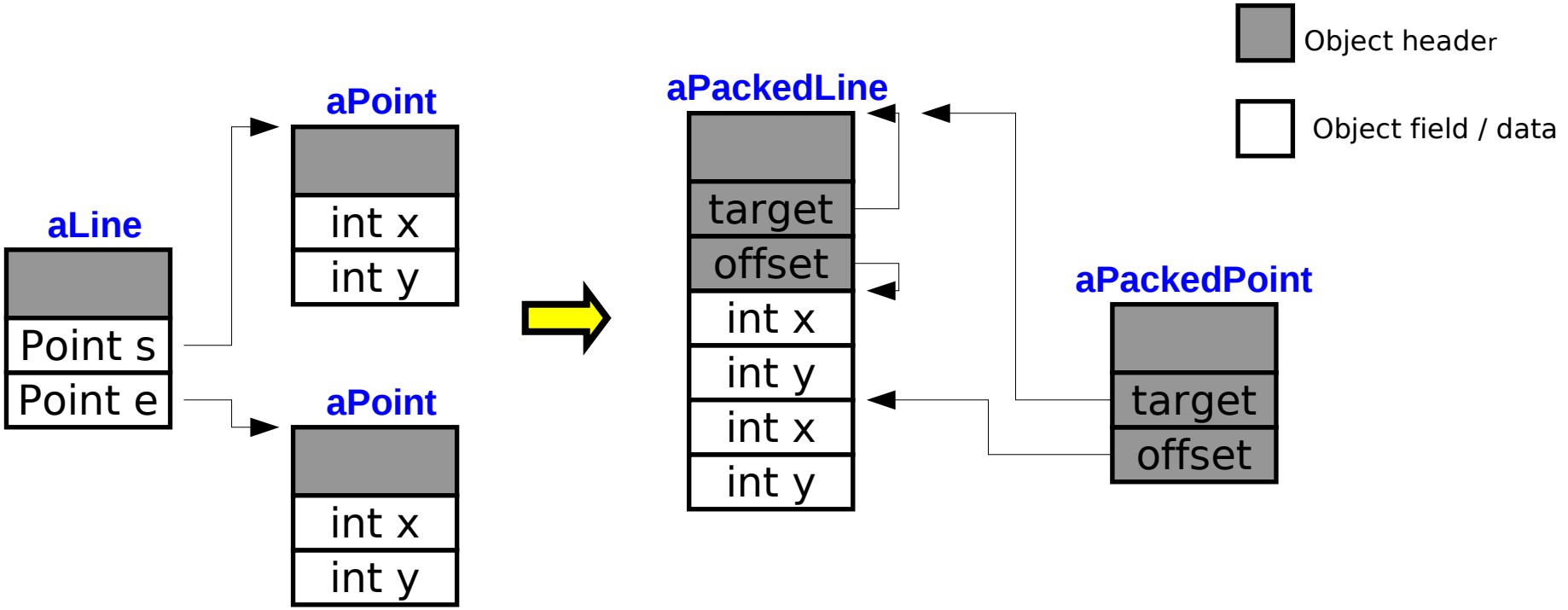


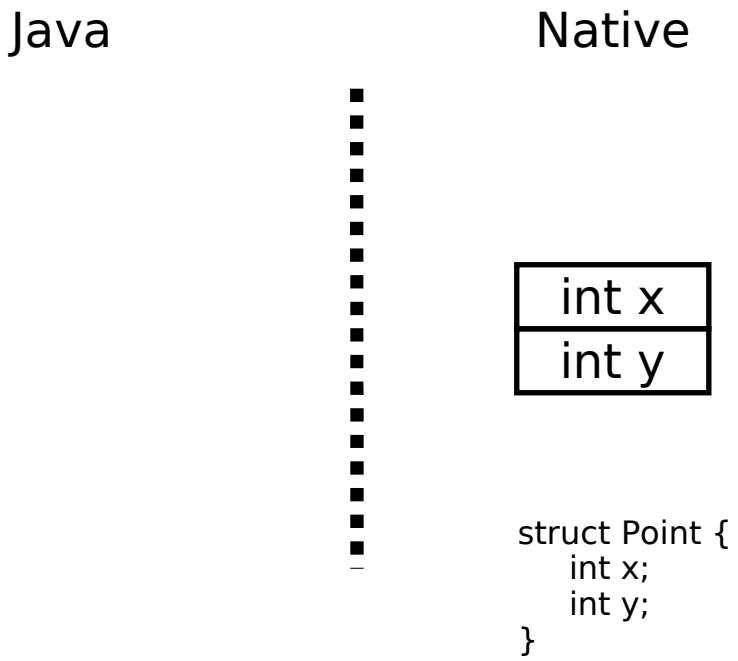

```
@Packed
final class PackedPoint extends PackedObject {
    int x;
    int y;
}

@Packed
final class PackedLine extends PackedObject {
    PackedPoint s;
    PackedPoint e;
}
```

Packed Objects: In Practice

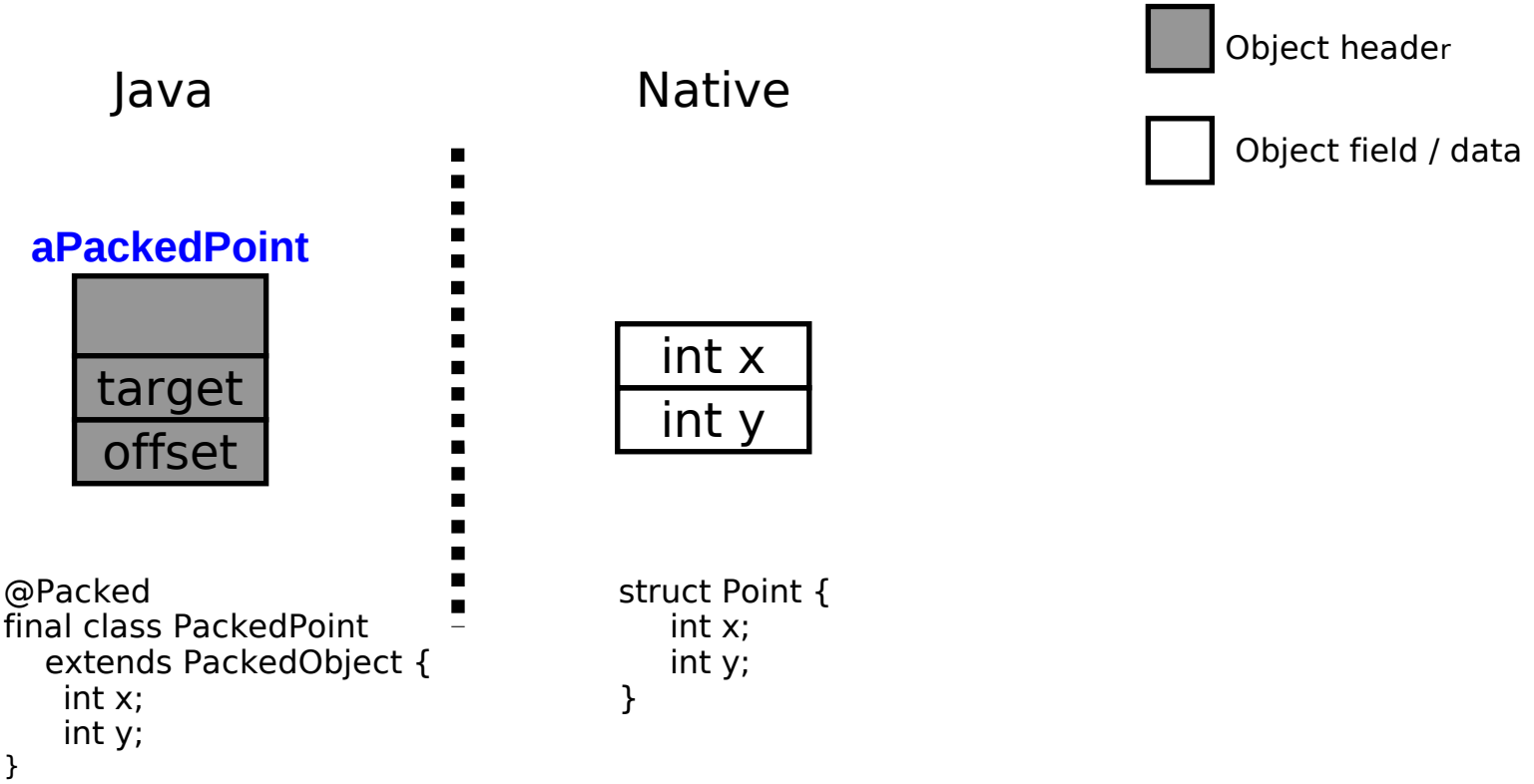


PackedPoint p = aPackedLine.e

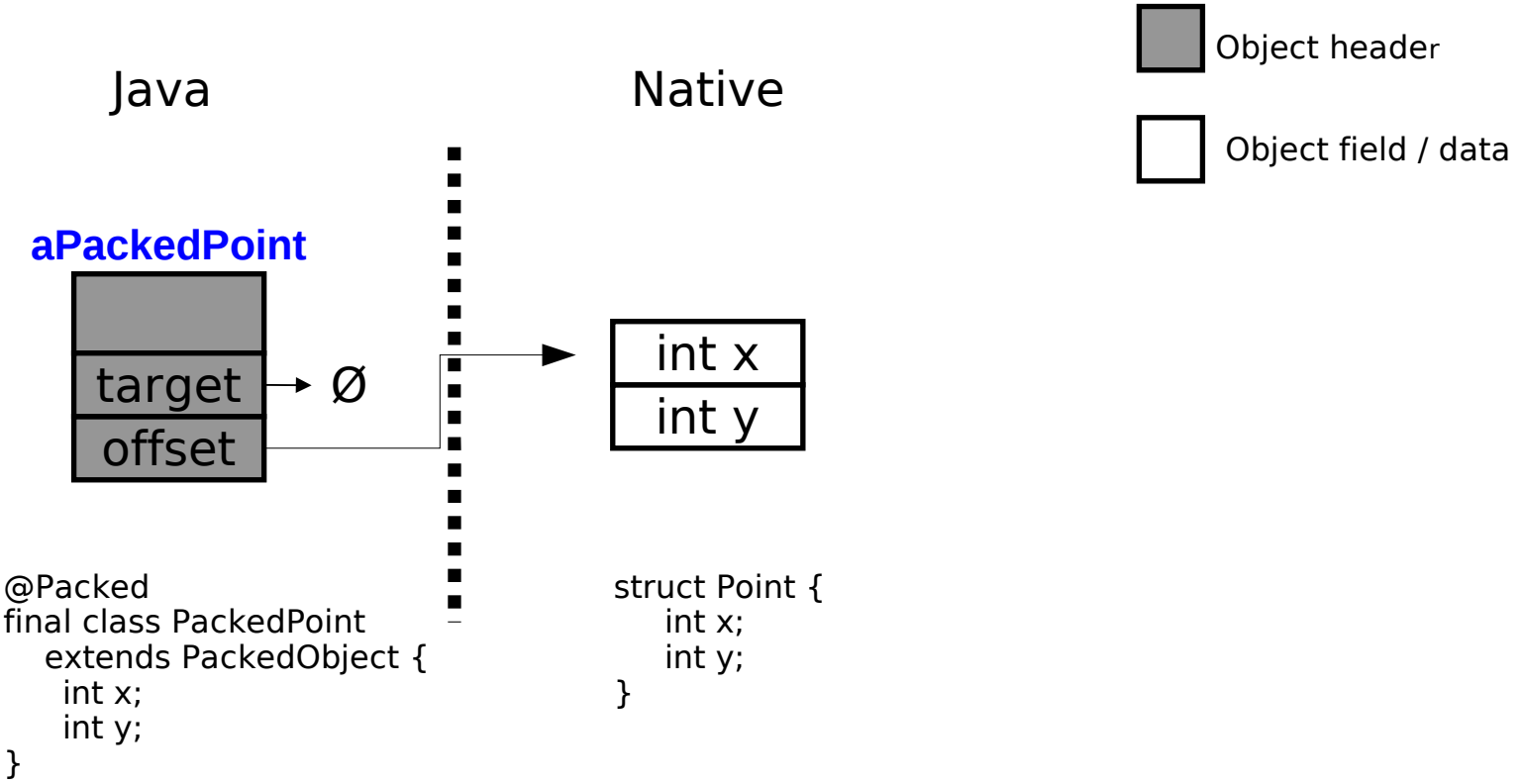
Packed Objects: In Practice with Native Access



Packed Objects: In Practice with Native Access

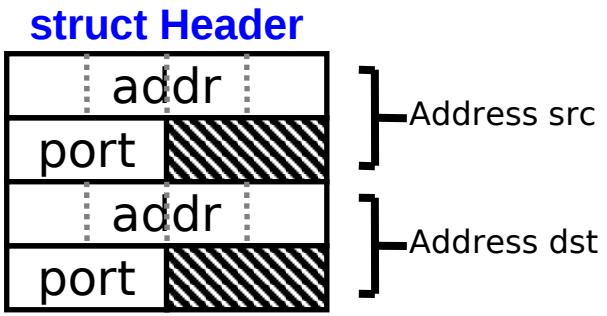


Packed Objects: In Practice with Native Access



Lets Build Something in C!

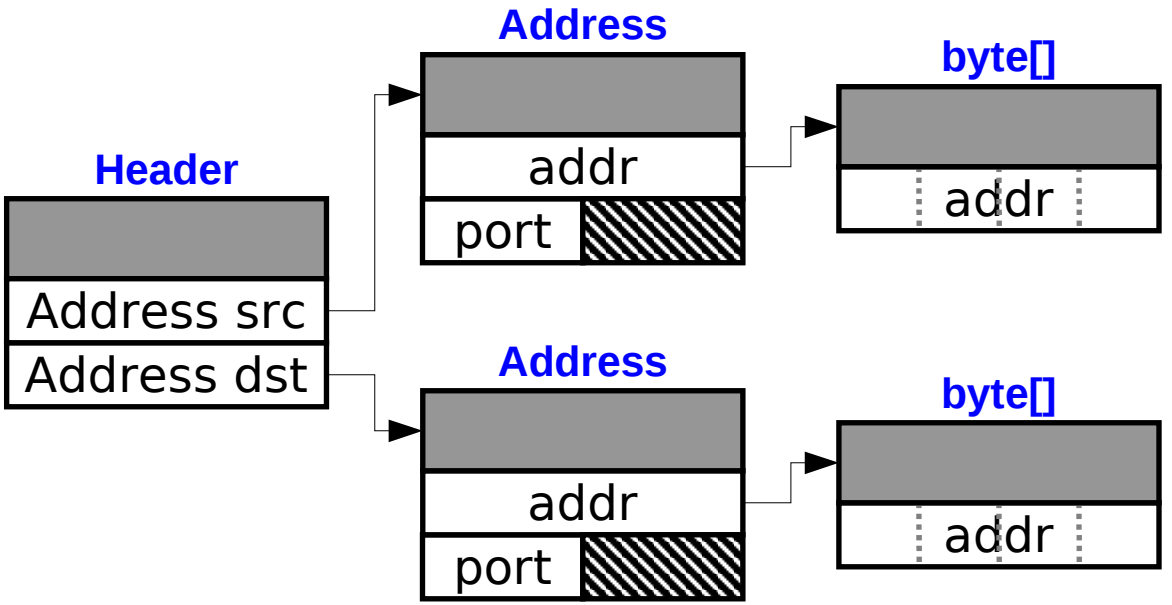
```
struct Address {
   char[4] addr;
   short port;
}
struct Header {
   struct Address src;
   struct Address dst;
}
```



- Nested substructures
- Compact representation
- Alignment aspects

Let's Build the Same "Something" in Java!

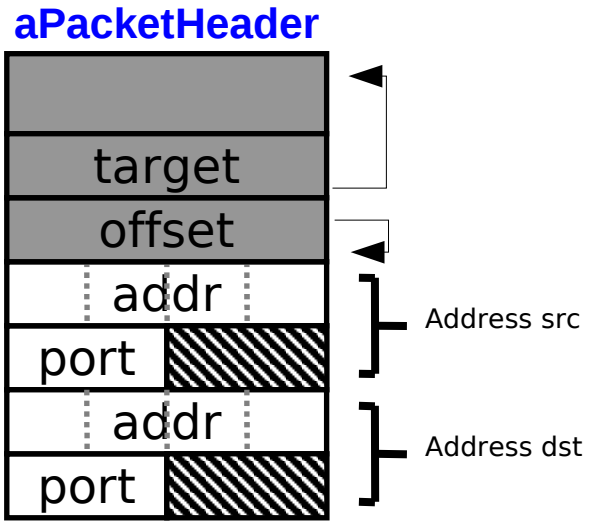
```
class Address {
        byte[] addr;
        short port;
}

class Header {
        Address src;
        Address dst;
}
```



- Headers
- No locality
- Alignment

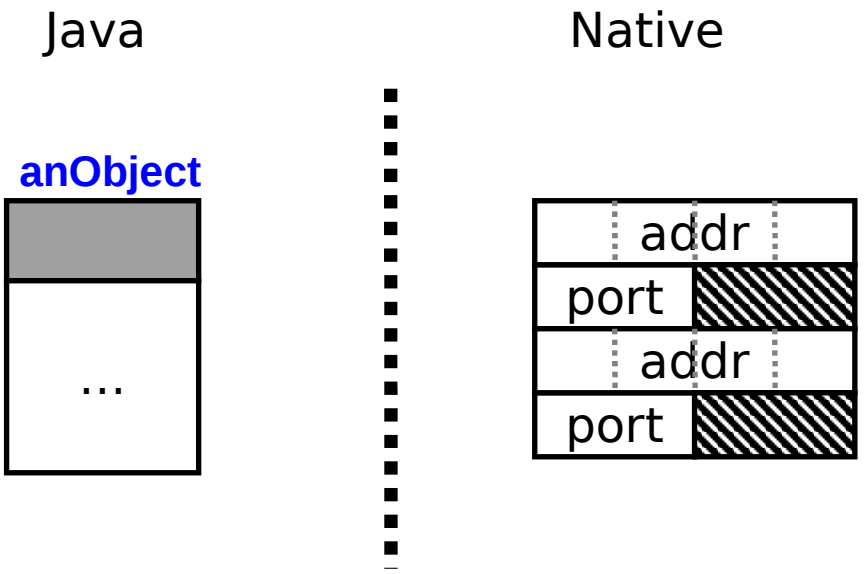
What if we did this with Packed Objects?

```
@Packed
final class Address extends PackedObject {
        PackedByte[[4]] addr;
        short port;
}

@Packed
final class PacketHeader extends PackedObject {
        Address src;
        Address dest;
}
```



- The Java code is pretty clean… and a pretty good result!

What about native access?



How do we implement this normally?

JNI implementation

```
public class PackedHeader {
    private long pointer;

    public byte[] getSourceAddress() { return getSourceAddressImpl(pointer); }
    public short getSourcePort() { return getSourcePortImpl(pointer); }
}
```

```
JNICALL jshort Java_pkg_PackedHeader_getSourcePort(JNIEnv* env, jobject recv, jlong pointer) {
   struct PacketHeader* header = (struct PacketHeader*)pointer;
   return (jshort)header->src.port;
}

JNICALL jbyteArray Java_pkg_PackedHeader_getSourceAddress(JNIEnv* env, jobject recv, jlong pointer) {
   struct PacketHeader* header = (struct PacketHeader*)pointer;
   jbyteArray result = (*env)->NewByteArray(env, 4);
   (*env)->SetByteArrayRegion(env, result, 0, 4, &(header->src.addr));
   return result;
}
```

- Usual “stash pointers in long types” tricks
- JNI costs tend to be high

DirectByteBuffer implementation

```
class PackedHeader {
    private ByteBuffer buffer;
    private static final int SRC_ADDR_OFFSET = 0;
    private static final int SRC_PORT_OFFSET = 4;
    private static final int DEST_ADDR_OFFSET = 8;
    private static final int DEST_PORT_OFFSET = 12;

    public short getSourcePort() { return buffer.getShort(SRC_PORT_OFFSET); }
    public byte[] getSourceAddress() {
        byte[] result = new byte[4];
        buffer.get(result, SRC_ADDR_OFFSET, 4);
        return result;
    }
}
```

- No extra JNI to write (this is good)
- Keeping your indices straight is never fun

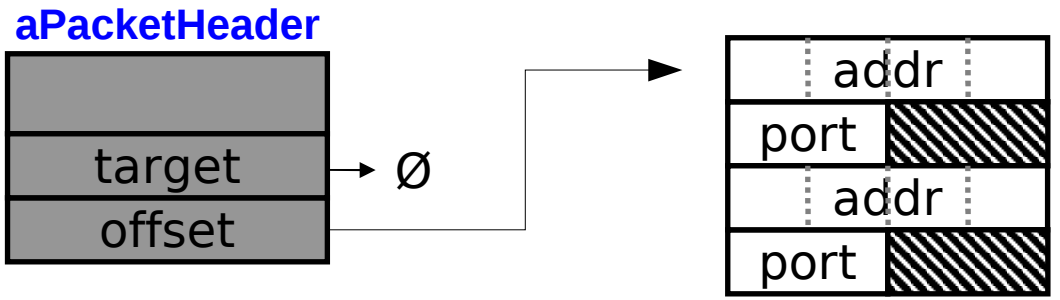
Unsafe implementation

```
class PackedHeader {
    private Unsafe unsafe;
    private long pointer;
    private static final int SRC_ADDR_OFFSET = 0;
    private static final int SRC_PORT_OFFSET = 4;
    private static final int DEST_ADDR_OFFSET = 8;
    private static final int DEST_PORT_OFFSET = 12;

    public short getSourcePort() { return unsafe.getShort(pointer + SRC_PORT_OFFSET); }
    public byte[] getSourceAddress() {
        byte[] result = new byte[4];
        unsafe.copyMemory(null, pointer + SRC_ADDR_OFFSET, result, 0, 4);
        return result;
    }
}
```

- You shouldn’t be here
- Still playing the indices game

PackedObject answer

```
final class PacketHeader extends PackedObject {
   Address src;
   Address dest;

   public short getSourcePort() { return src.port; }
   public PackedByte[] getSourceAddress() { return src.addr; }
}
```



- Looks like natural Java code
- Foregoes JNI
- Same type capable of on-heap representation

Active work and next steps

- Experimenting with this now
- Yes, there are security aspects to be aware of here
- This is potentially part of a larger look at Java / Platform interop
- Not specifically viewed as a cure to GC problems
- This forms the basis for many other solutions to existing problems…

Questions?

References

- **Get Products and Technologies:**
  - IBM Java Runtimes and SDKs:
    - https://www.ibm.com/developerworks/java/jdk/
  - IBM Monitoring and Diagnostic Tools for Java:
    - https://www.ibm.com/developerworks/java/jdk/tools/
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