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Packed Objects

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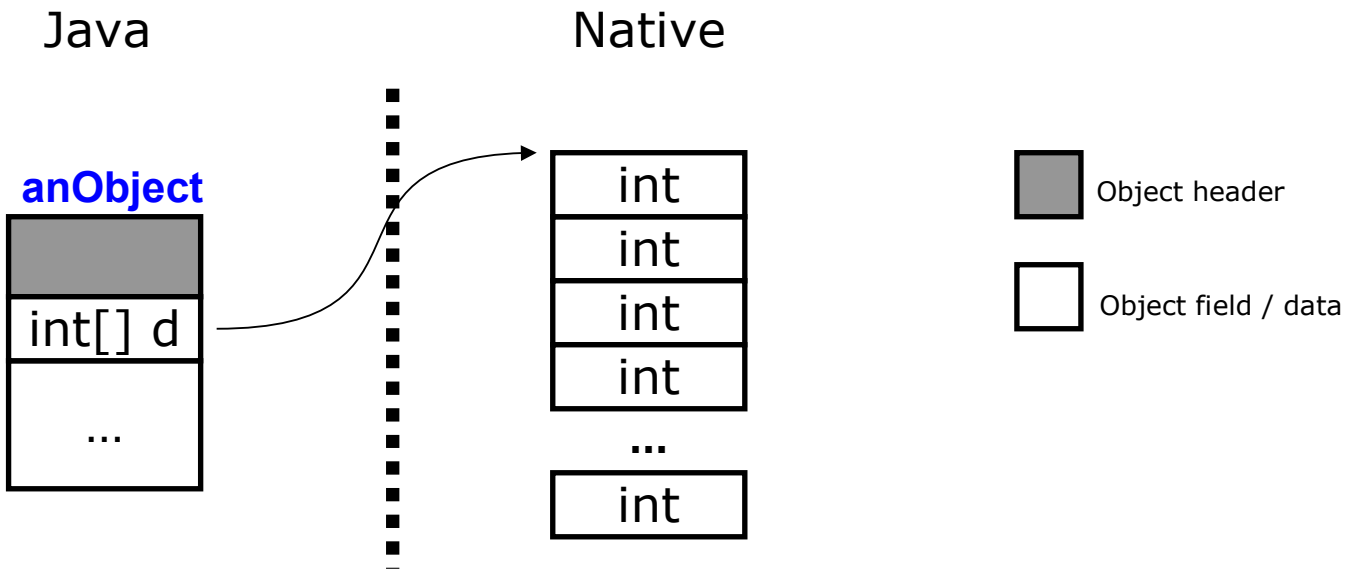
Problem

Problem? What problem?

- JNI just isn't a great way to marshal data
- Locality in Java can matter (e.g., JEP 142)
- Existing native and data placement stories aren't very good
- In many cases, legacy systems exist – the interop is just terrible

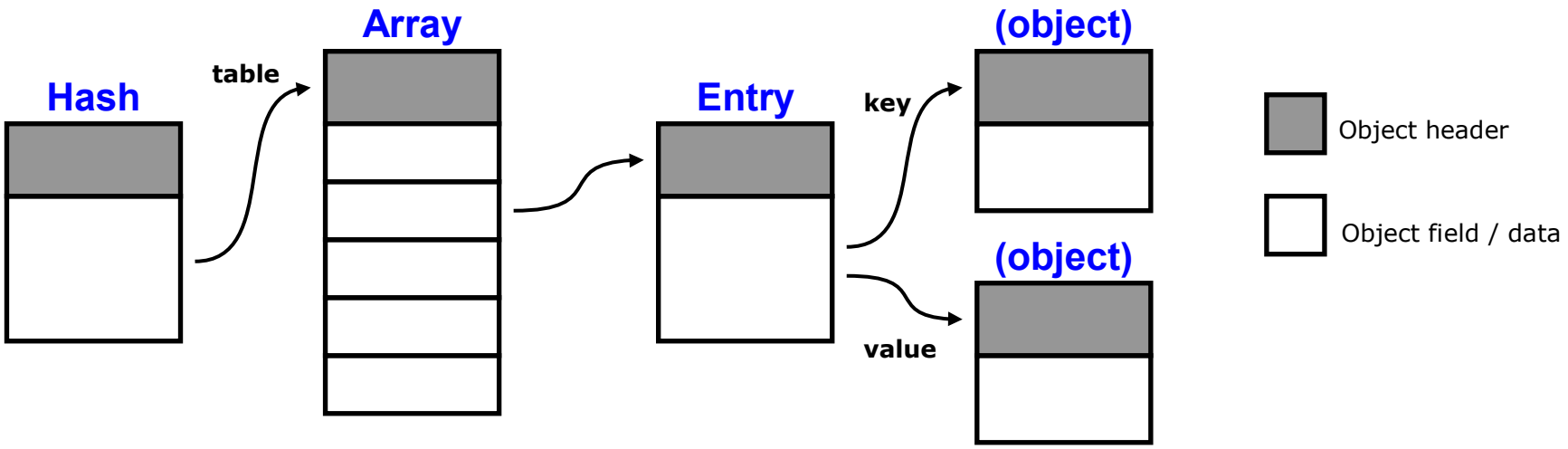
- So we want something that integrates well with the Java language and helps us…

Native Access

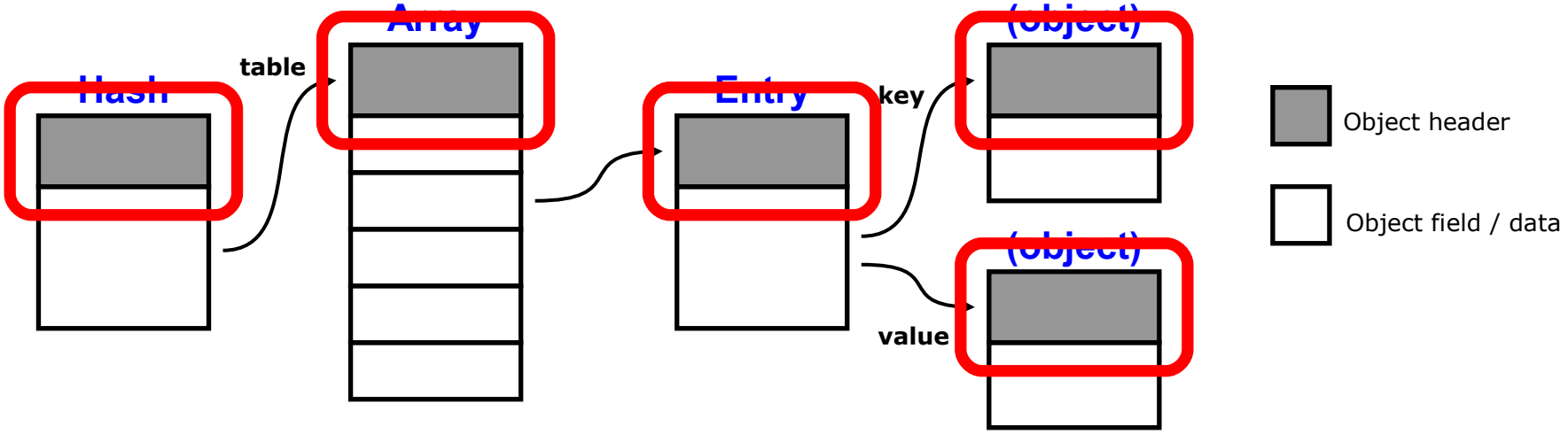


Fighting the Java/Native interface

Everything is an Object



Everything is an Object



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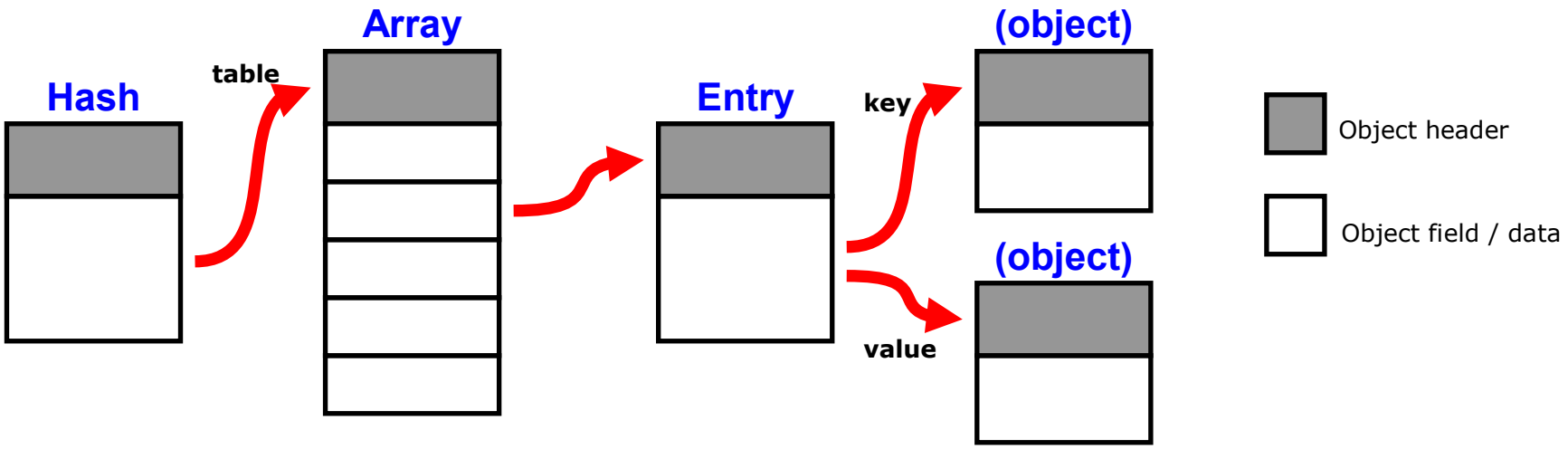

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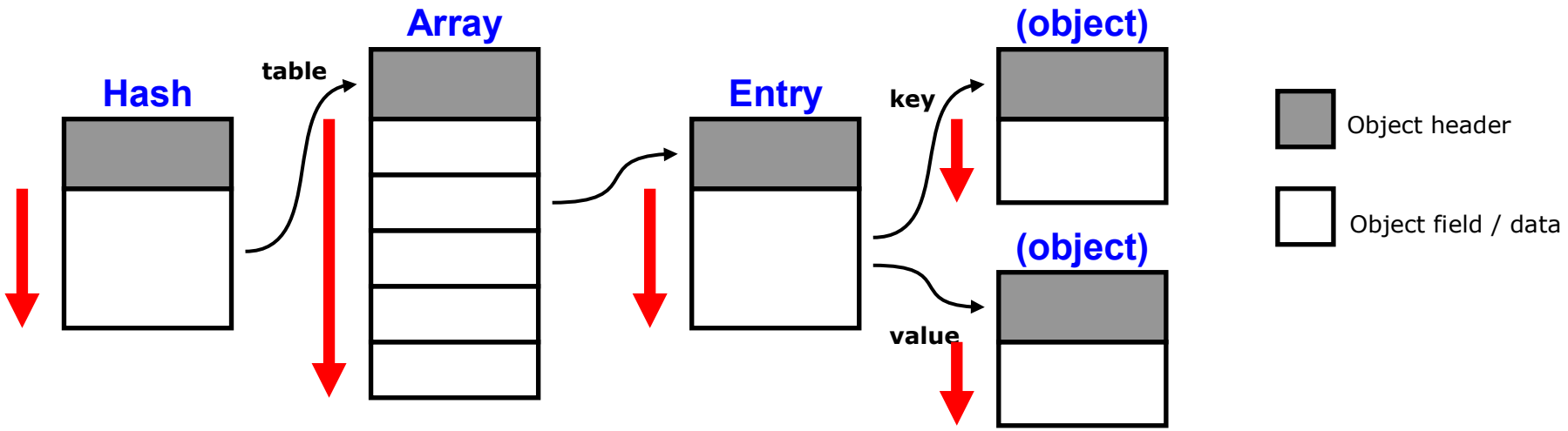
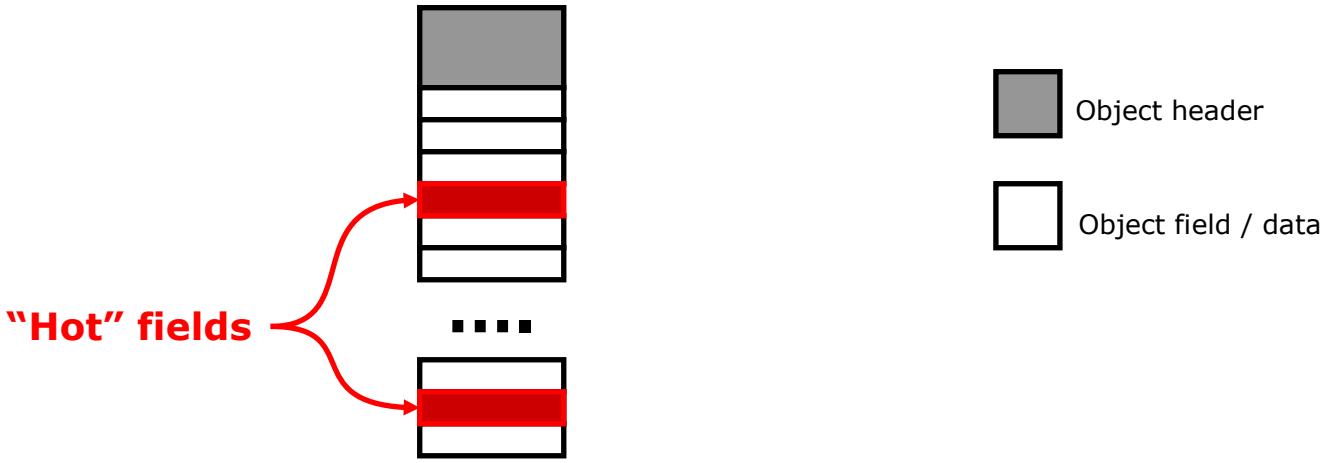


Object Internals



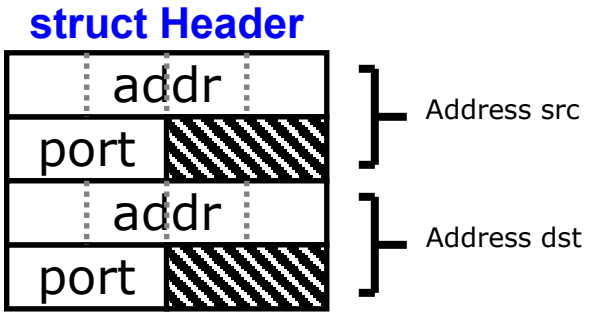
- Field ordering has performance implications
- JVM can potentially reorder your fields for you

Establishing Goals

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

- This actually sounds a lot like C structure types

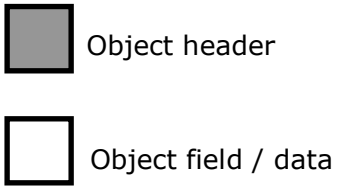
```
struct Address {
  char[4] addr;
  short port;
}
struct Header {
  struct Address src;
  struct Address dst;
}
```

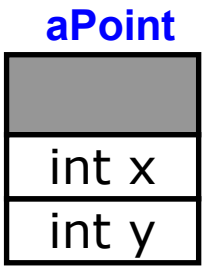


- Packed Objects!

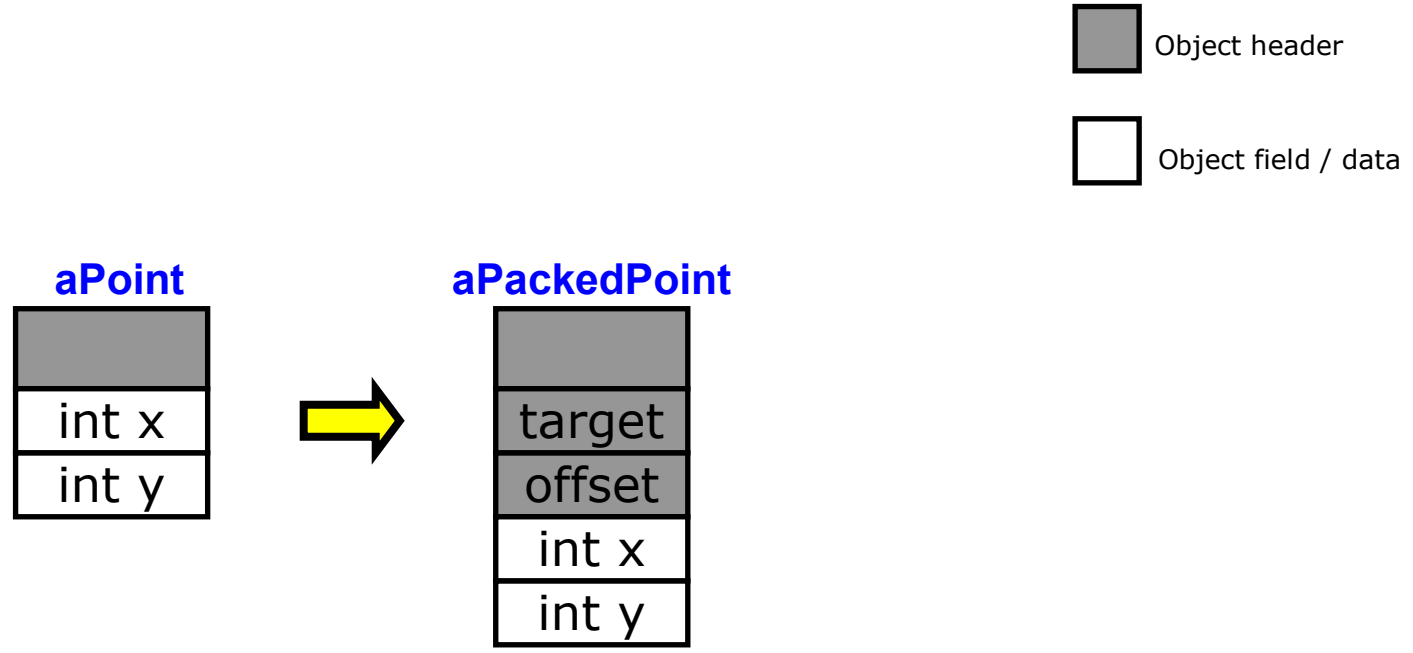
Basics

Packed Objects: Under the covers

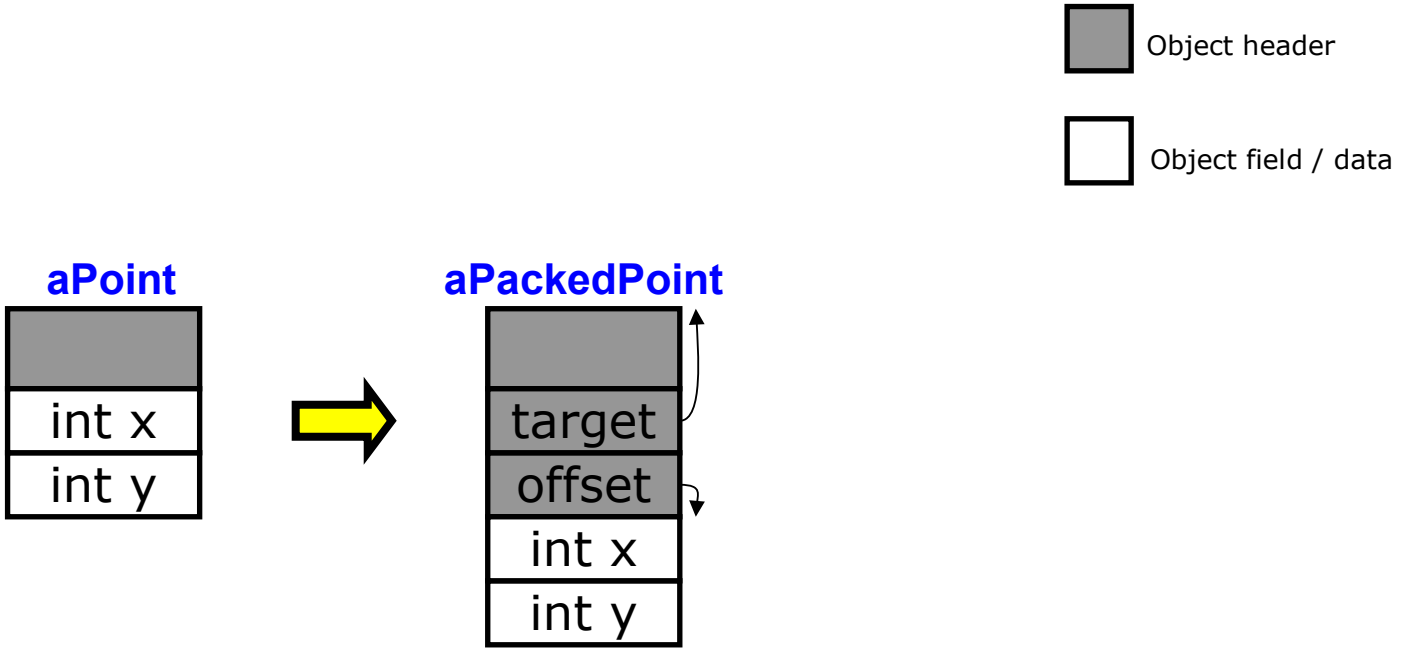




Packed Objects: Under the covers



Packed Objects: Under the covers



Packed Objects: In Practice

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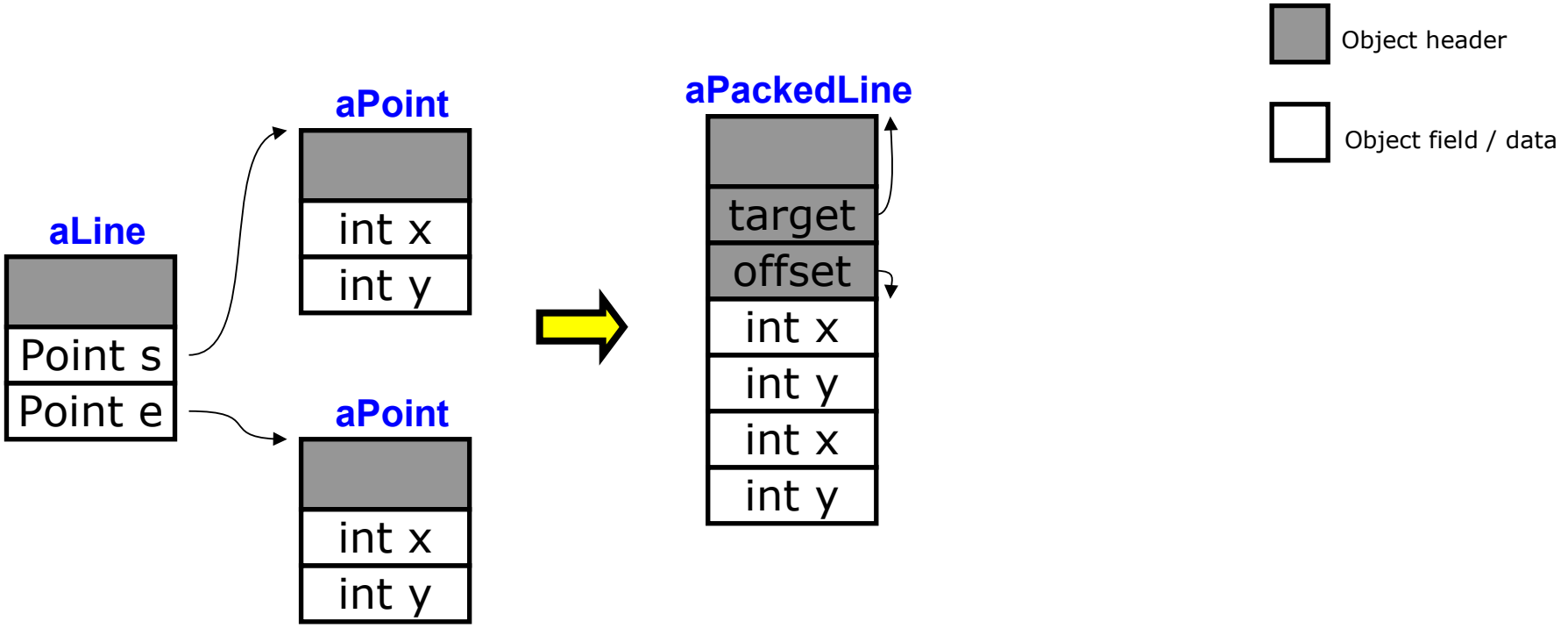

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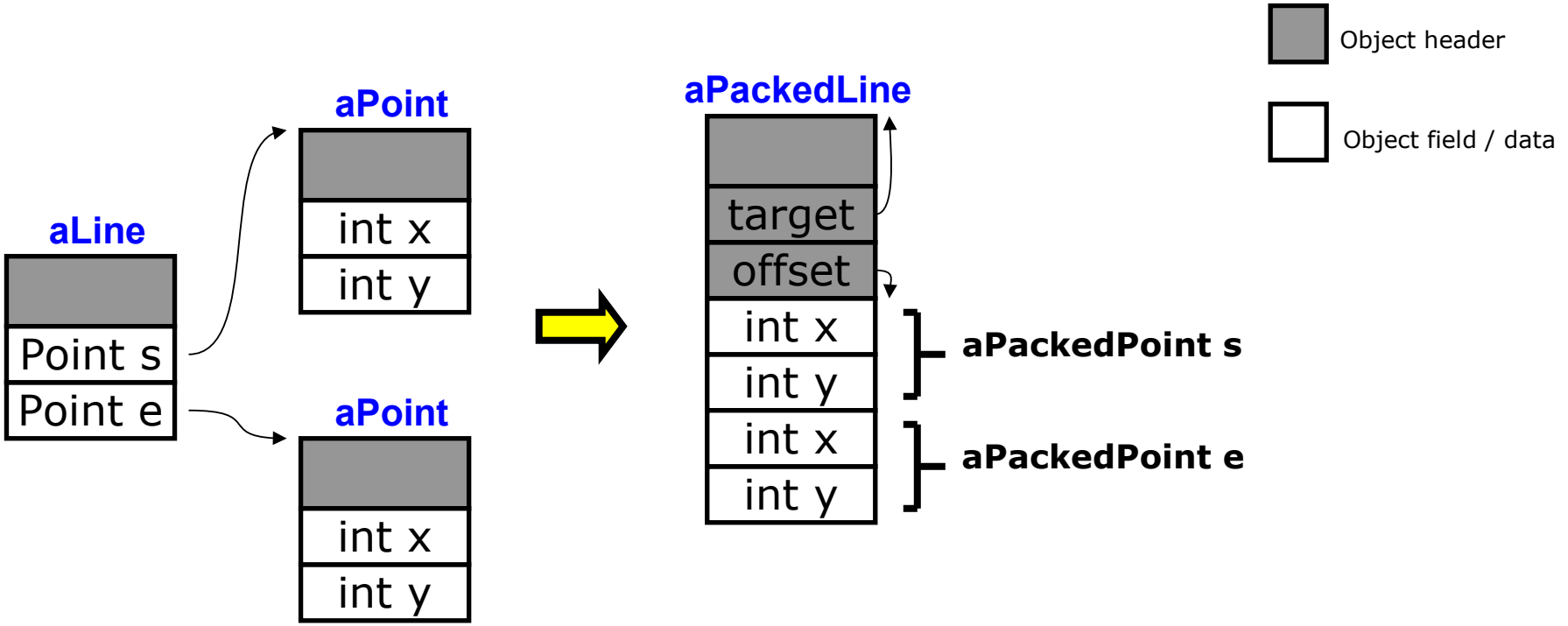
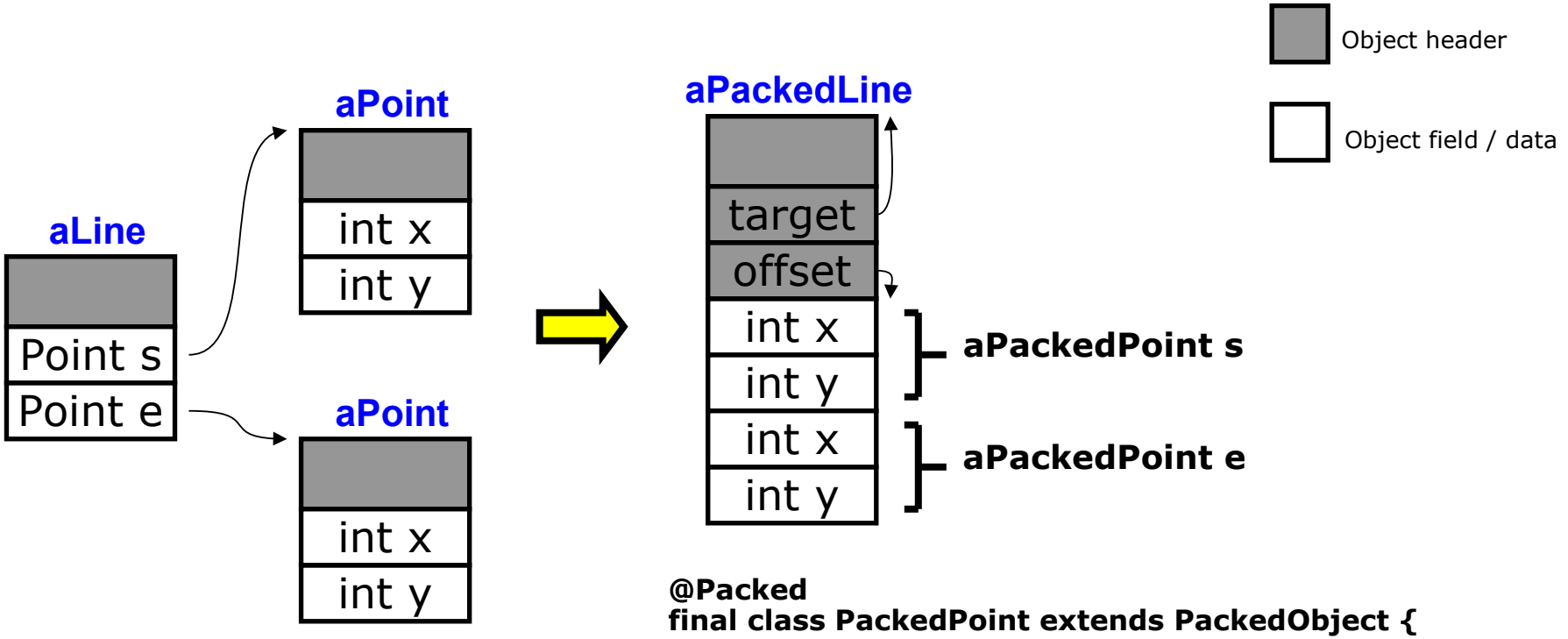


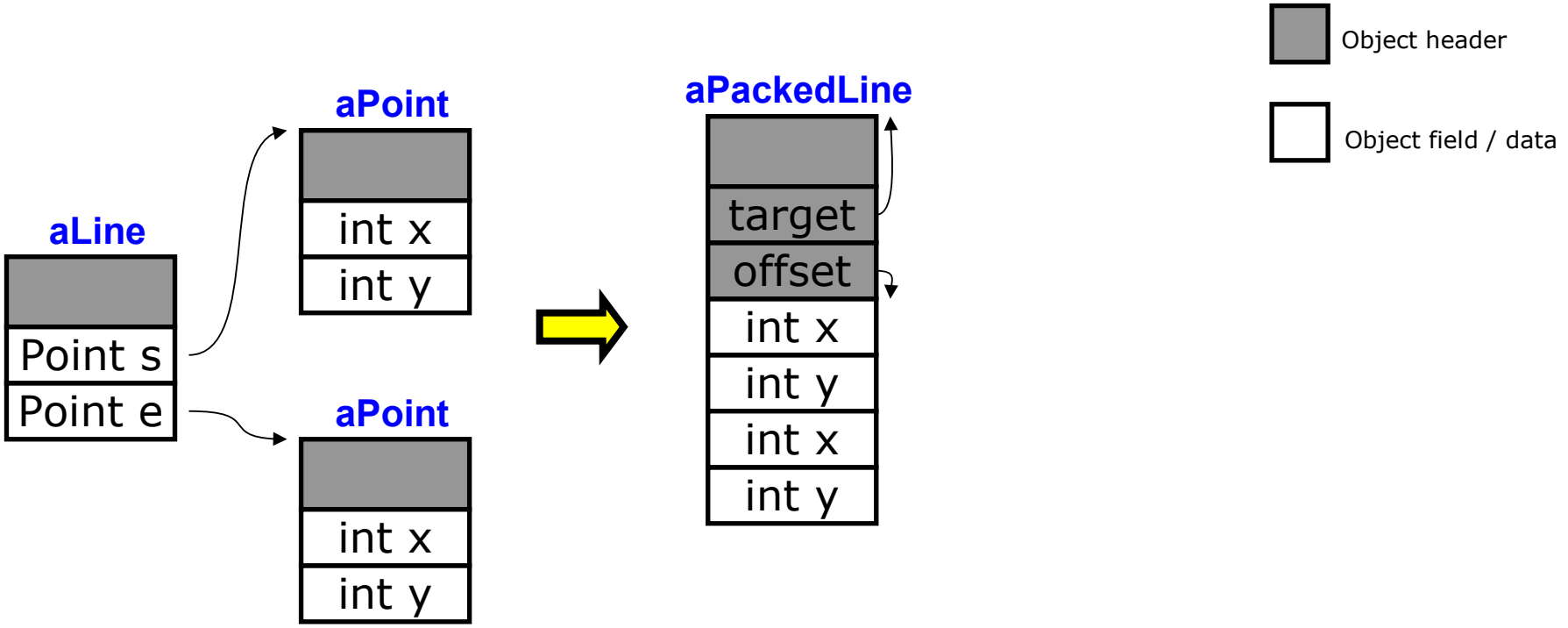
Packed Objects: In Practice



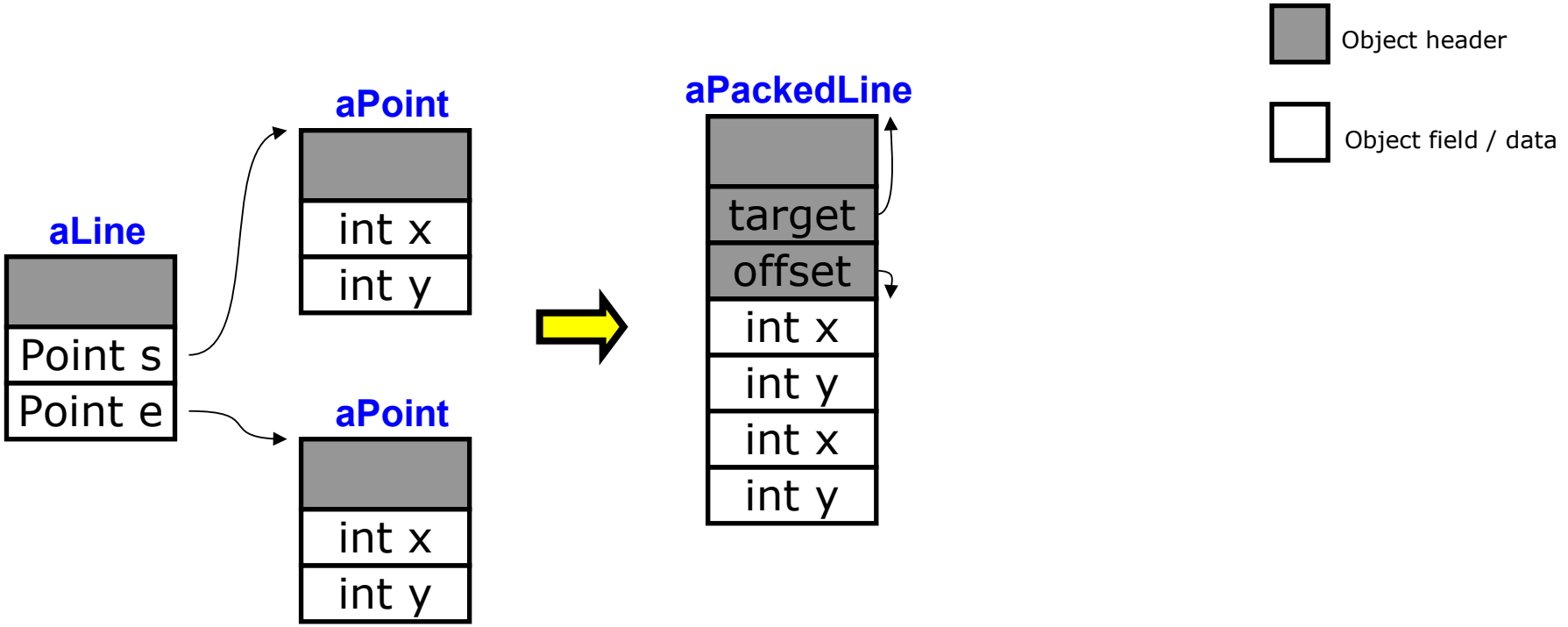

```
@Packed
final class PackedPoint extends PackedObject {
    int x;
    int y;
}

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

Packed Objects: In Practice

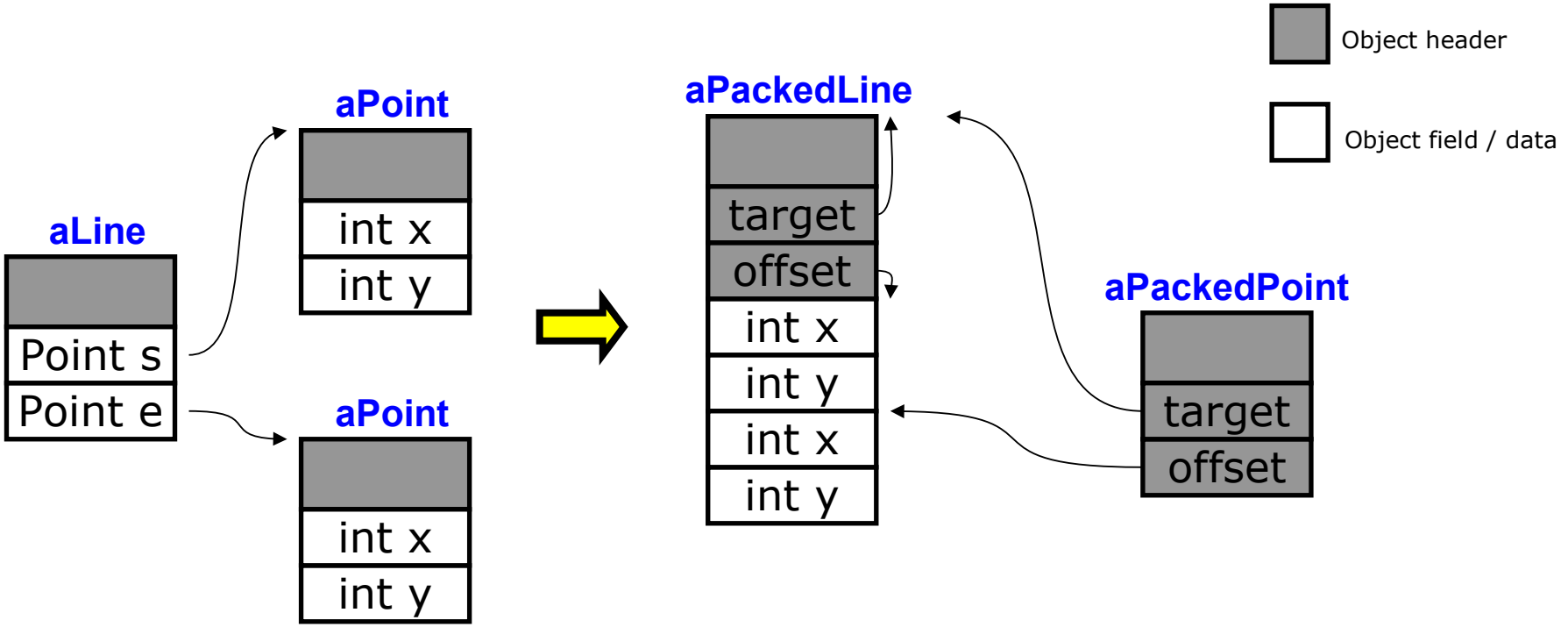


Packed Objects: In Practice



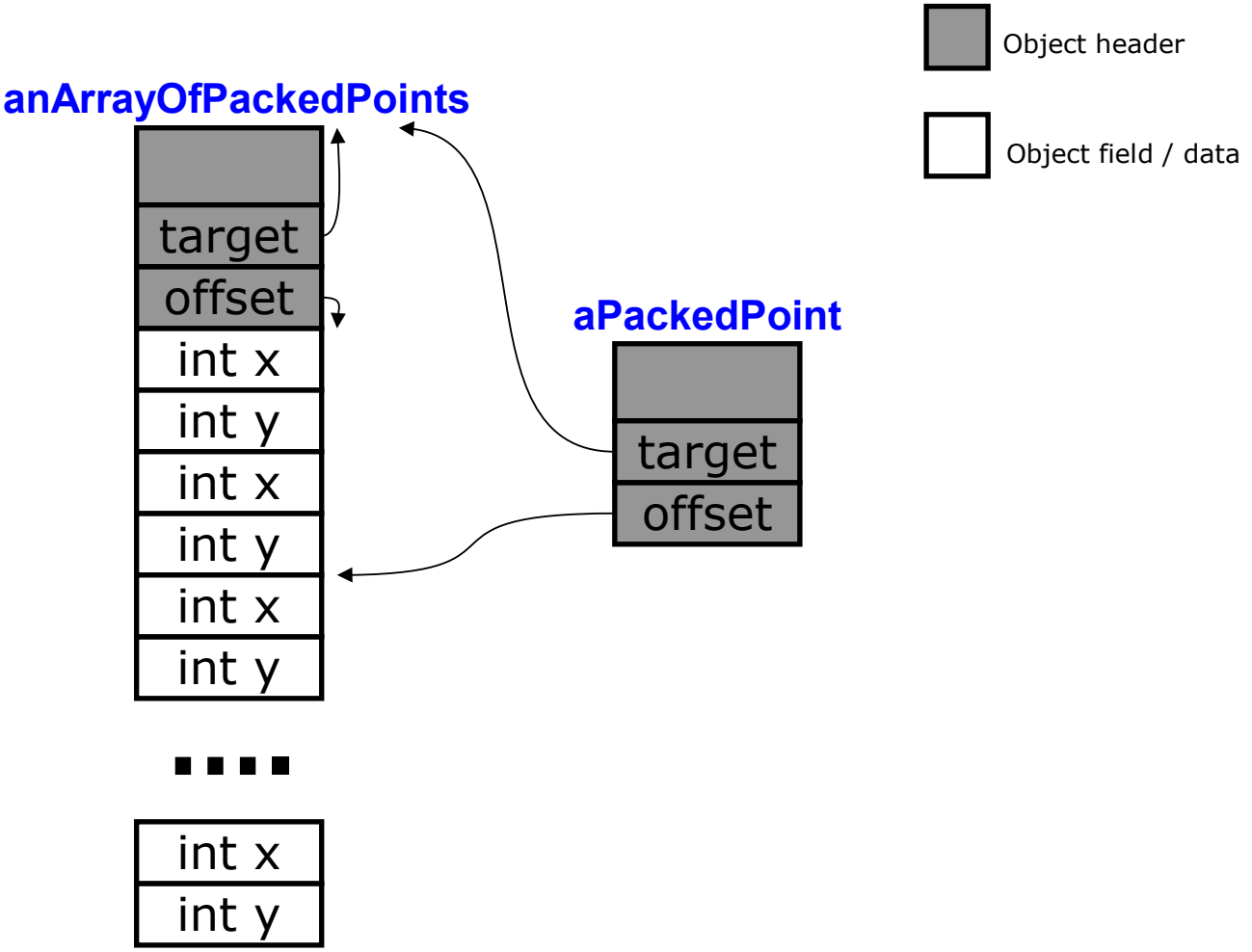
aPackedLine.e

Packed Objects: In Practice

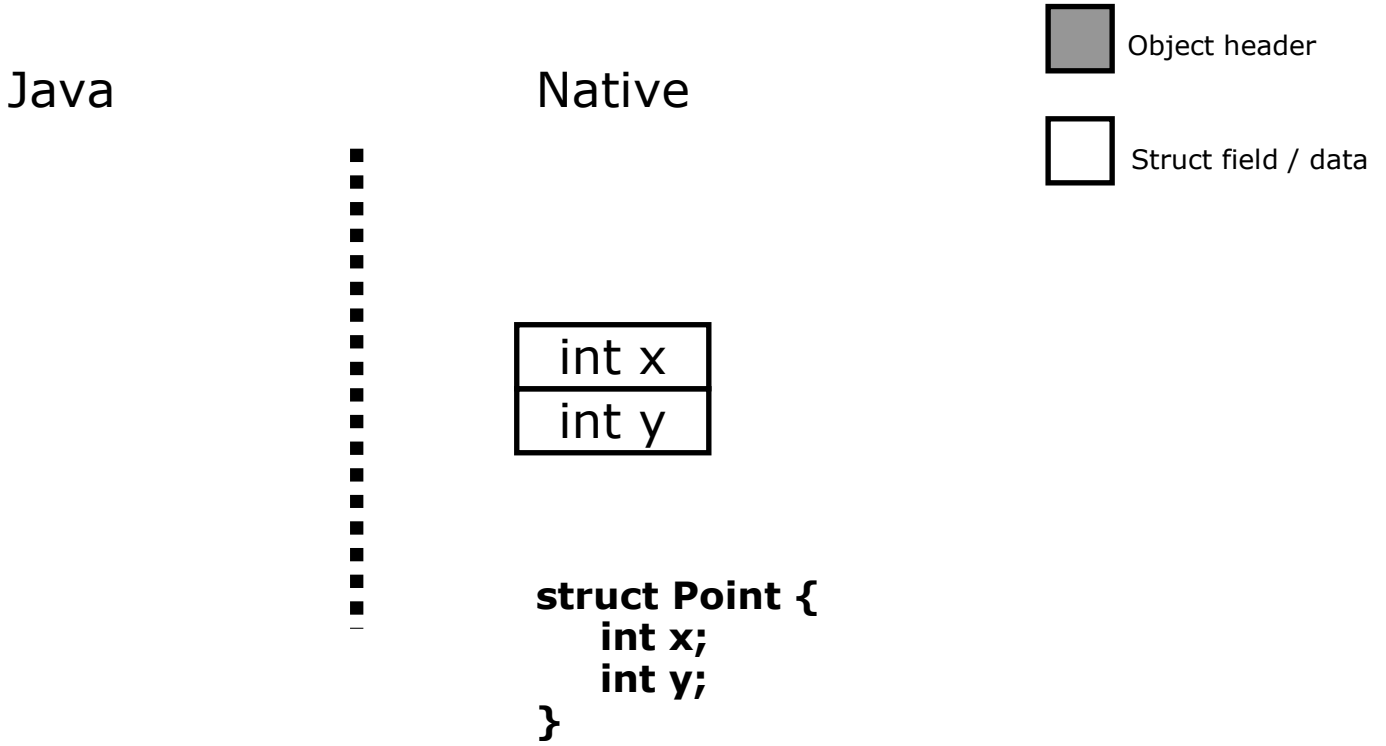


aPackedLine.e

Packed Objects: In Practice with Arrays



Packed Objects: In Practice with Native Access



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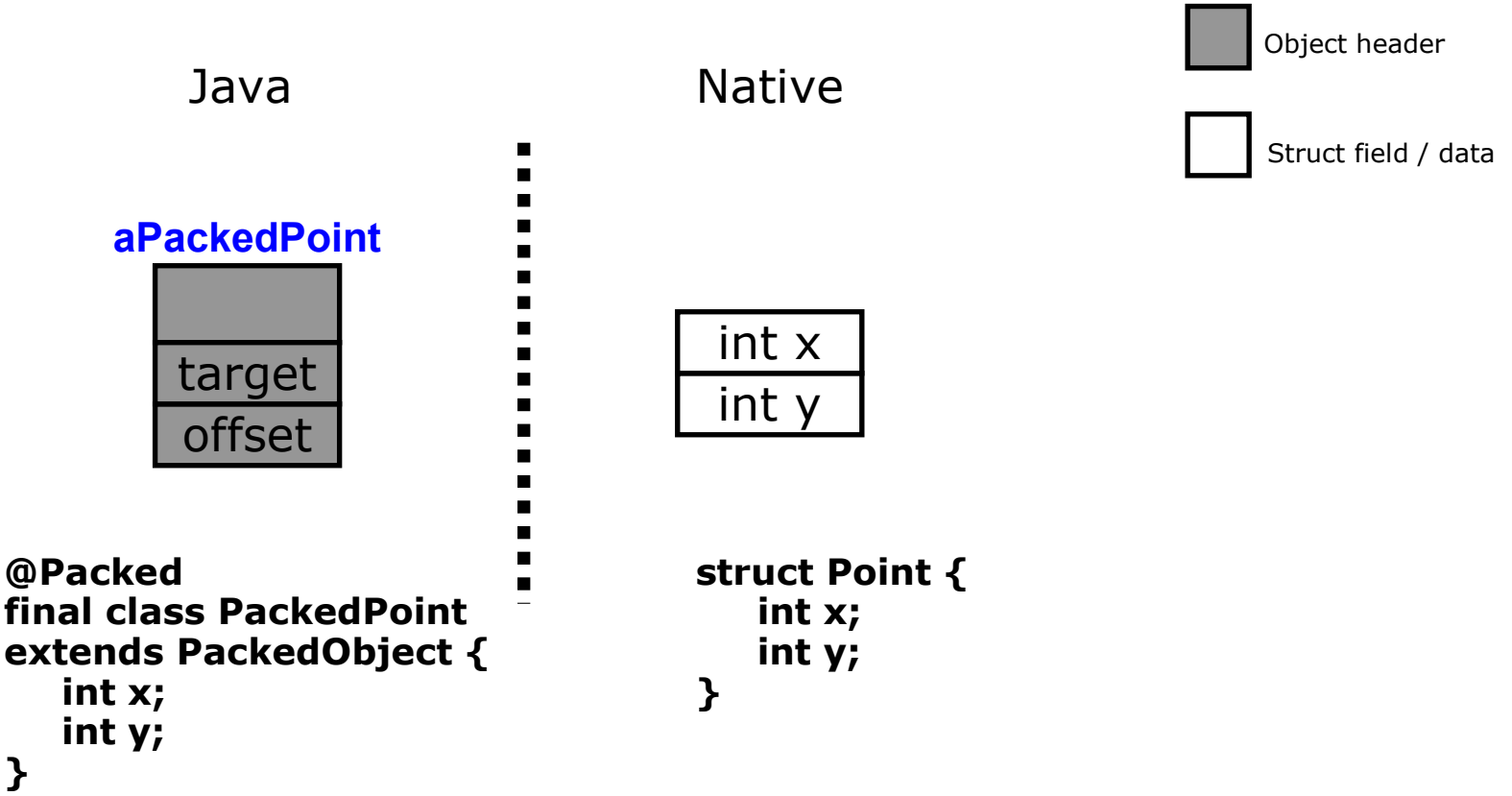
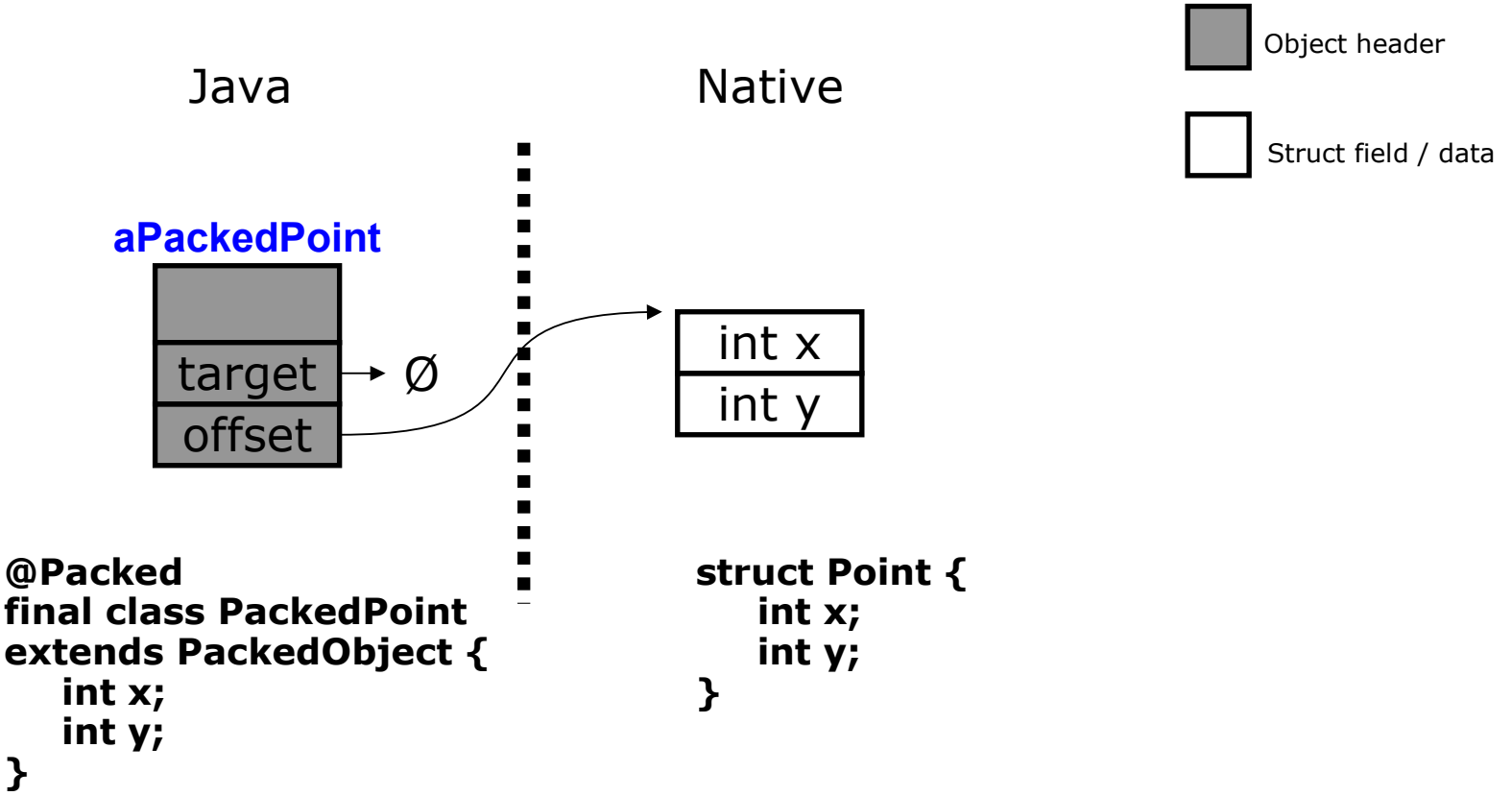


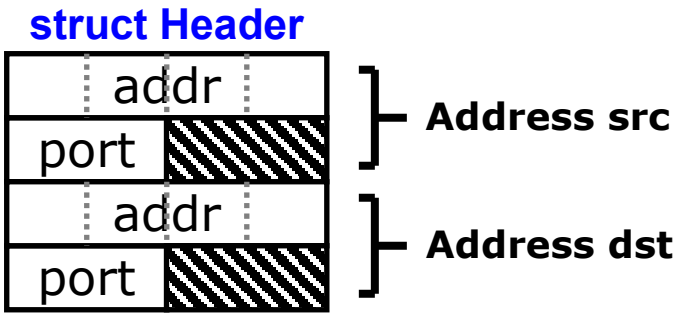
Packed Objects: In Practice with Native Access



Advantages

Lets Build Something in C!

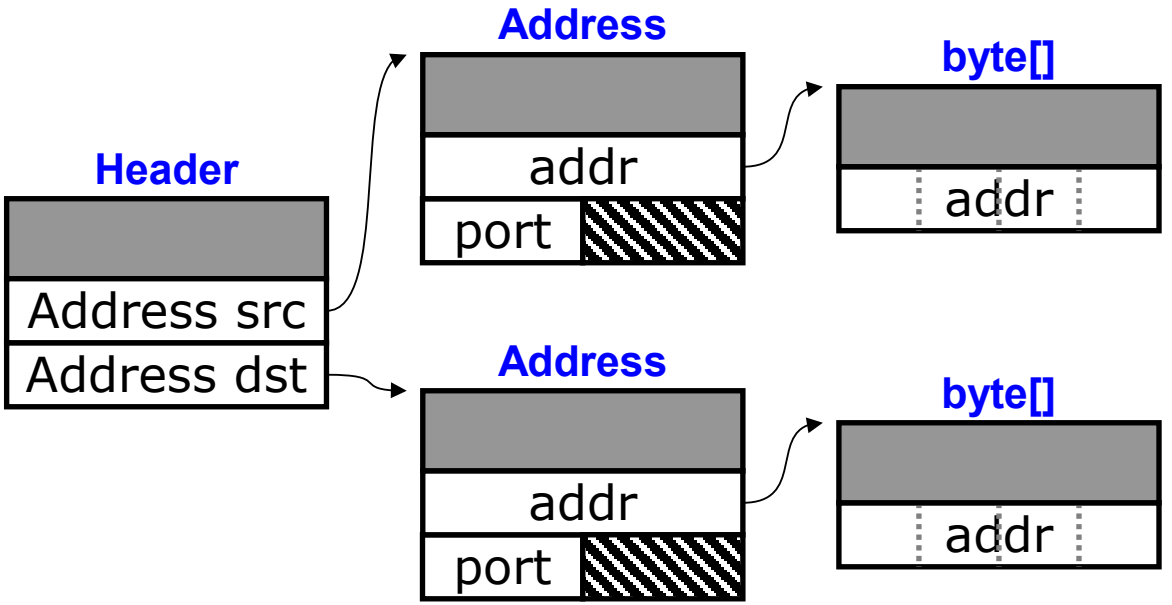
```
struct Address {
   char[4] addr;
   short port;
}
struct Header {
   struct Address src;
   struct Address dst;
}
```



- Nested substructures
- Compact
- Alignment

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

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

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



- Headers
- Locality
- Alignment

What does the Java code look like under the covers?

```
if(header.dst.addr[0] == (byte)192) {
    // ...
}
```

Bytecodes:

```
aload1
getfield Header.dest  LAddress;
getfield Address.addr [B
iconst0
baload
bipush 192
ificmpeq …
```

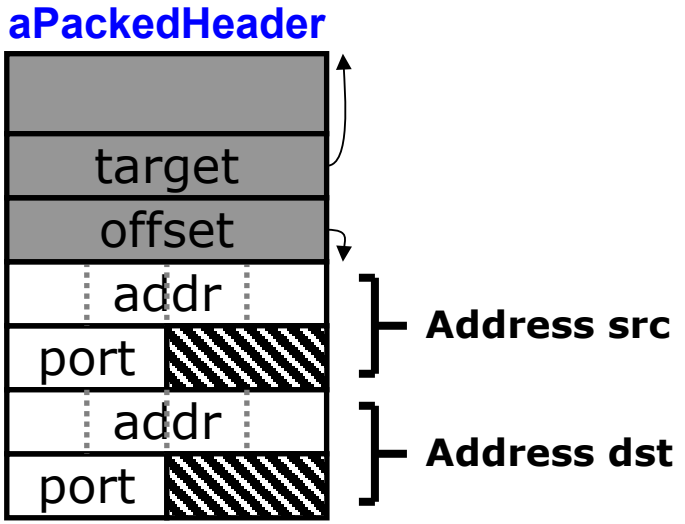
JIT (32 bit):

```
mov EBX, dword ptr -4[ECX]    // load temp1
mov EBX, dword ptr 8[EBX]     // load dest
mov EBX, dword ptr 4[EBX]     // load addr
movsx EDI, byte ptr 8[EBX]    // array[0]
cmp EDI, 192
```

- From a code point of view, this isn't terrible…

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!

Ok, what about the code under the covers?

```
if(header.dst.addr[[0]] == (byte)192) {
    // ...
}
```

Bytecodes:

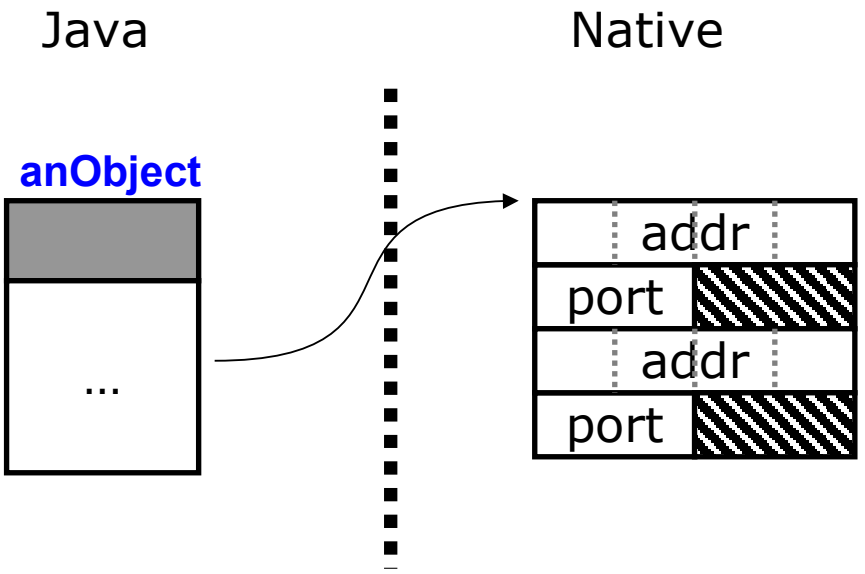
```
aload1
getfield PackedHeader.dest
    LAddress;
getfield Address.addr [B
iconst0
baload
bipush 192
ificmpeq …
```

JIT (32 bit):

```
mov EBX, dword ptr -4[ECX]    // load temp1
mov EAX, dword ptr 4[EBX]     // load target
mov EDX, dword ptr 8[EBX]     // load offset
lea EBX, dword ptr [EAX + EDX]
movsx EDI, byte ptr 0[EBX]    // array[0]
cmp EDI, 192
```

- Bytecodes don’t change… JIT code is pretty good too!

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

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

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
- Keeping your indices straight is never fun

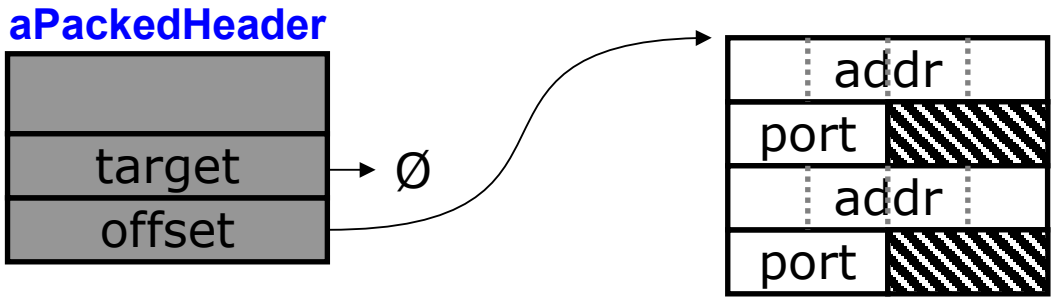
DirectByteBuffer implementation

```
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)
- Still playing the indices game

PackedObject answer

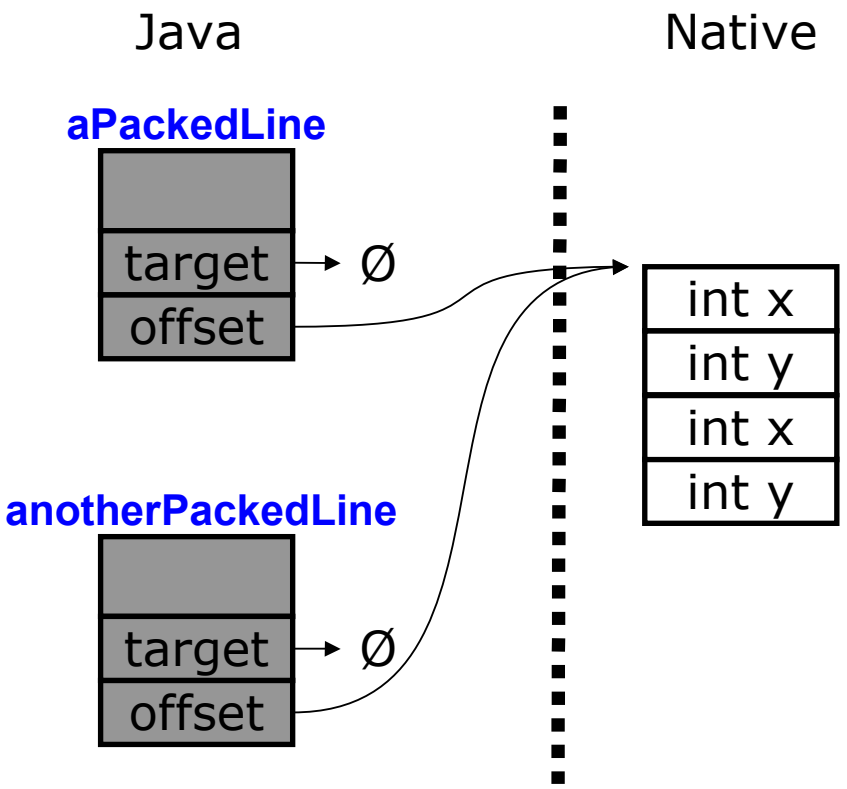
```
final class PacketHeader extends PackedObject {
   Address src;
   Address dest;

   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

Challenges

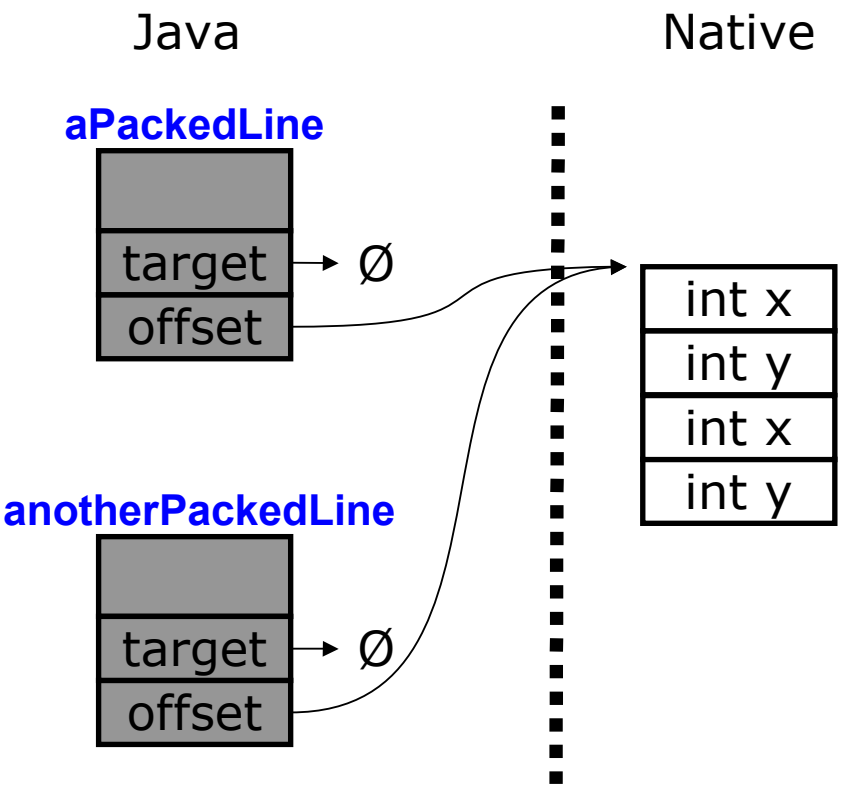
Identity Crisis



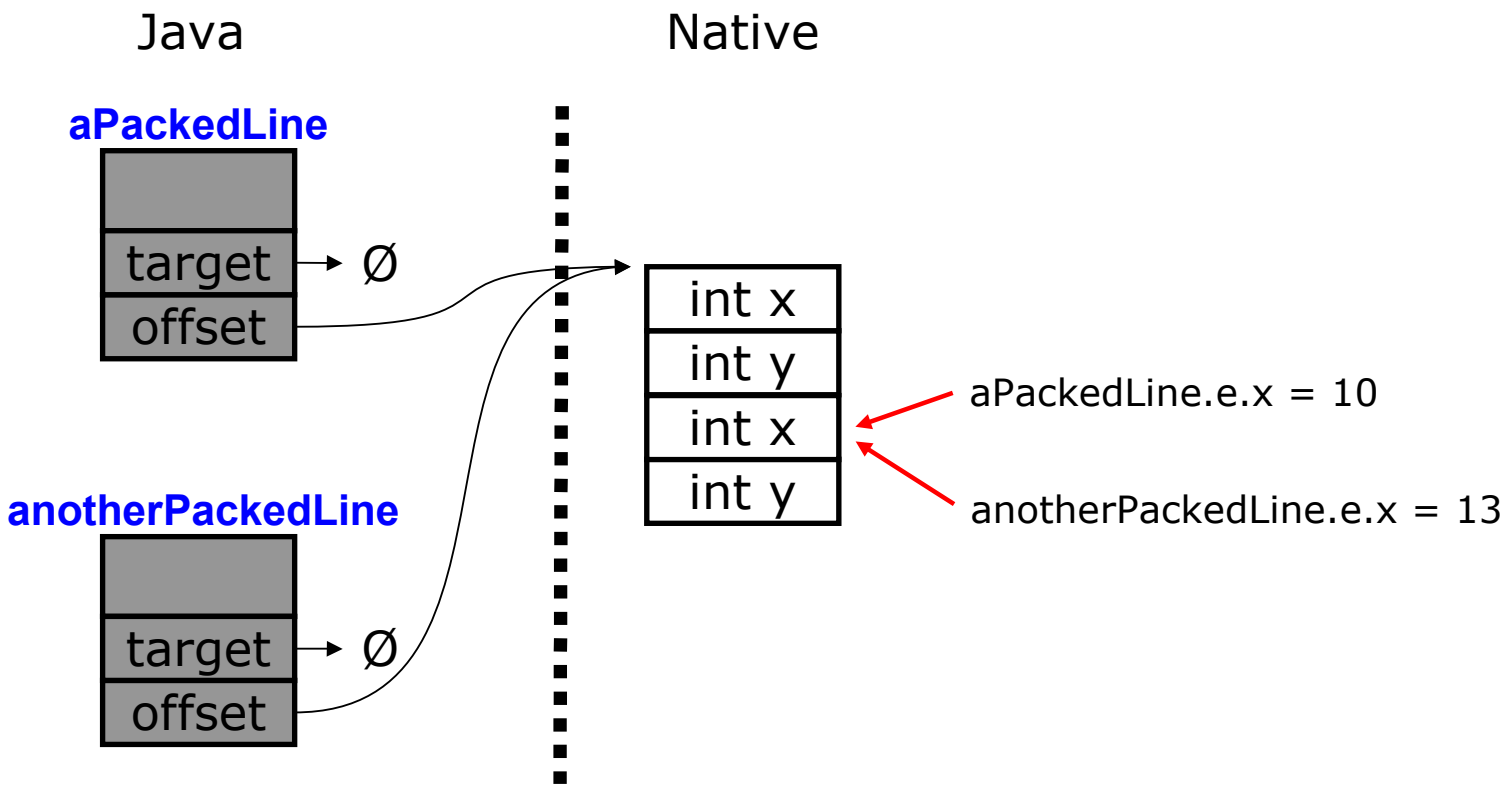
What does `aPackedLine == anotherPackedLine` mean?

→ The data is what really matters

Synchronization



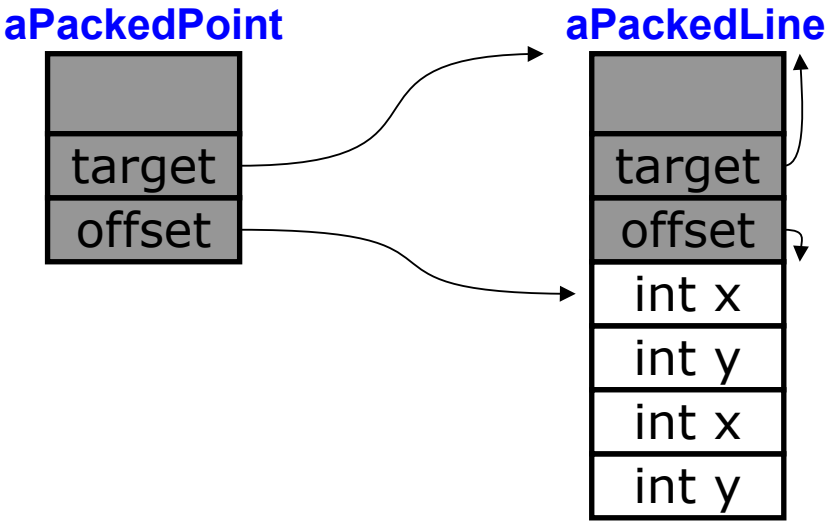
Synchronization



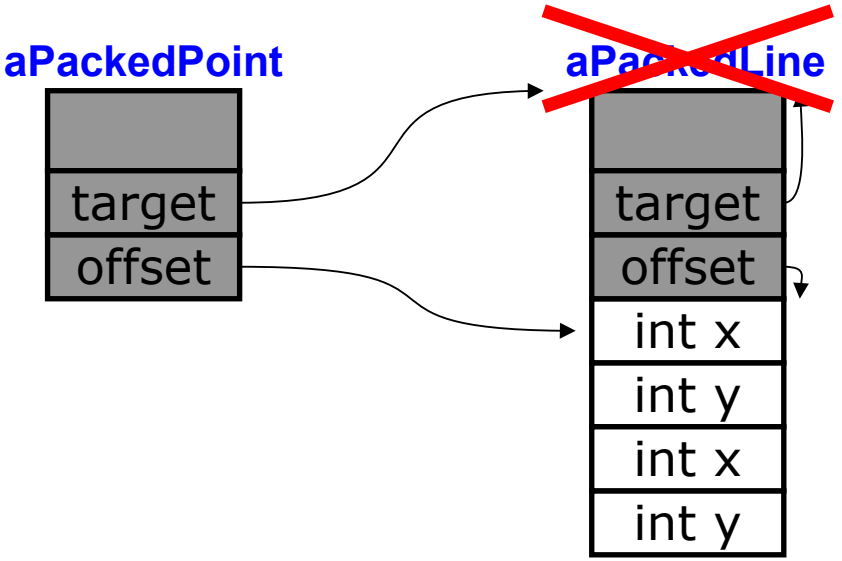

```
Thread T1:
synchronized (aPackedLine) {
        aPackedLine.e.x = 10;
}
```

```
Thread T2:
synchronized (anotherPackedLine) {
        anotherPackedLine.e.x = 13;
}
```

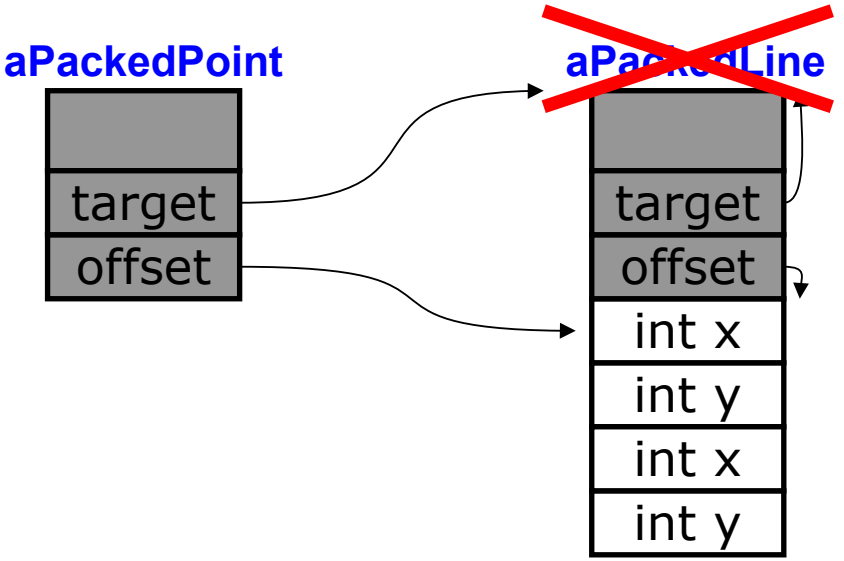
Finalization



Finalization

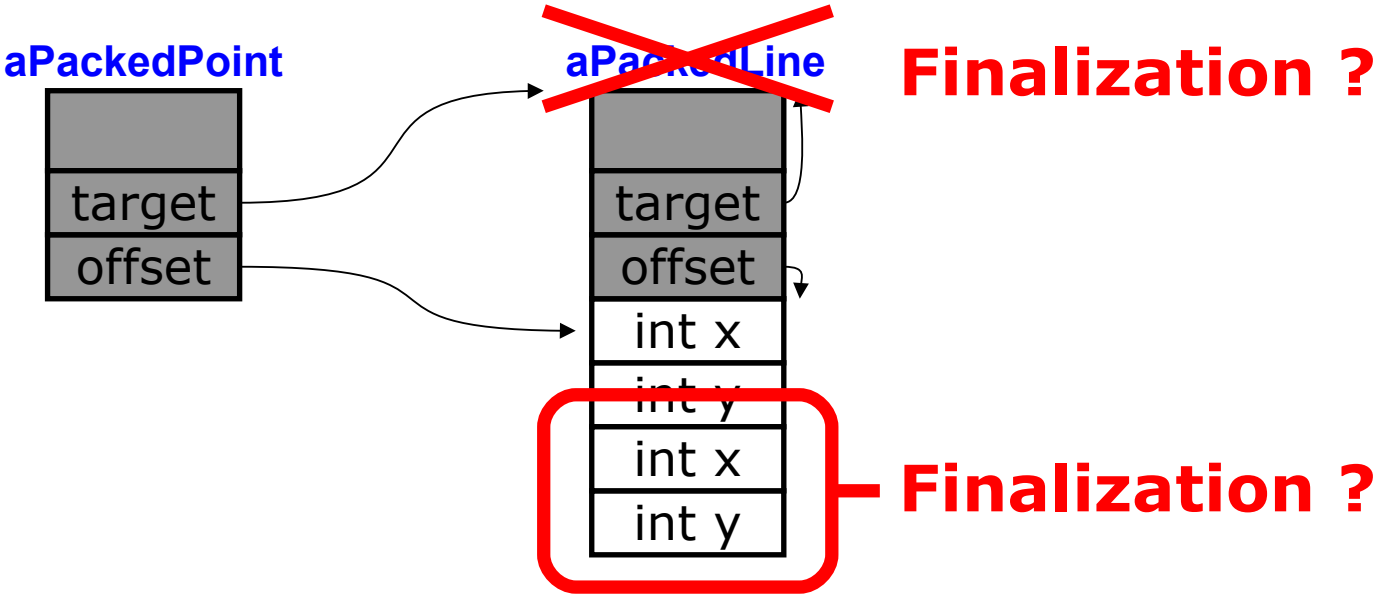


Finalization

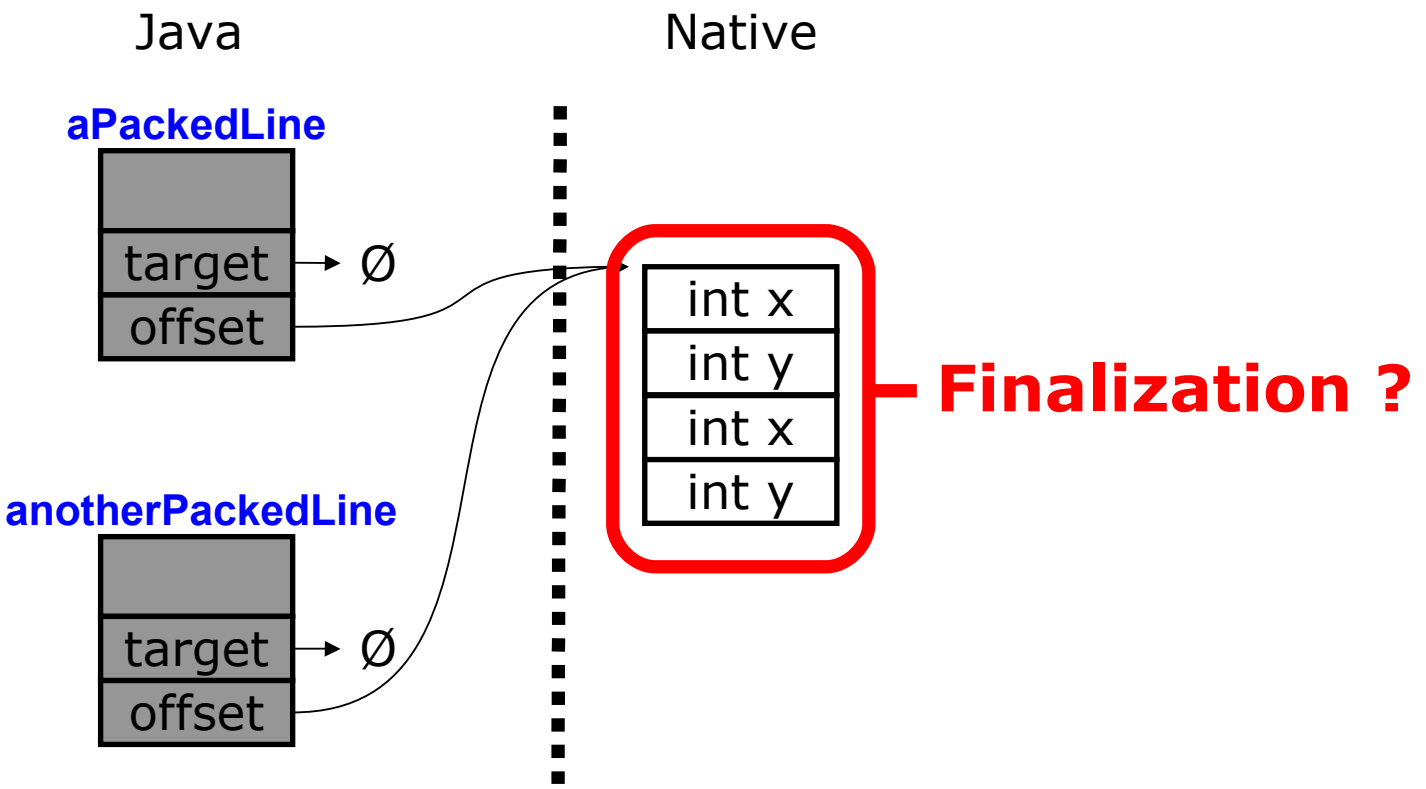


Finalization ?

Finalization

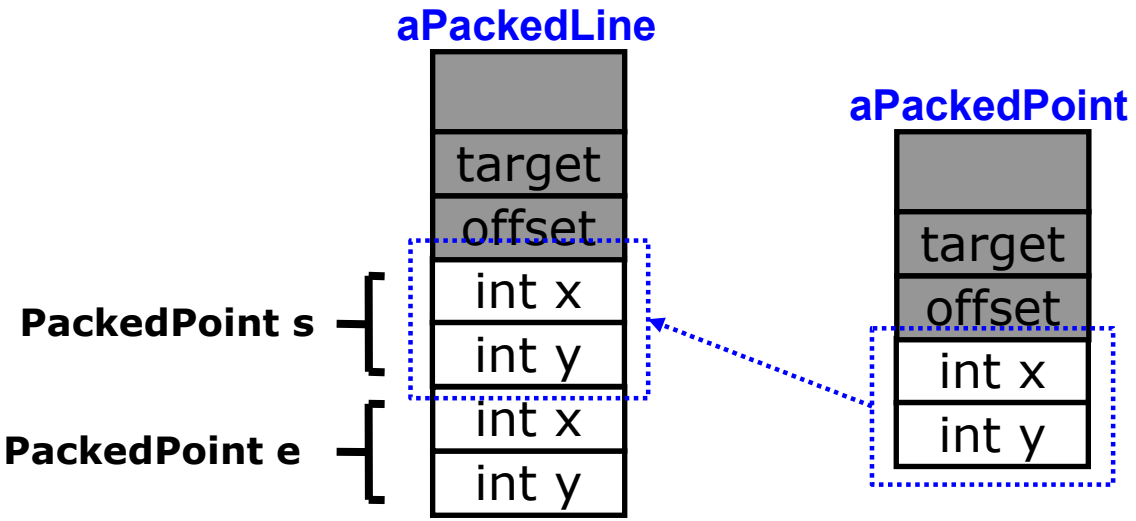


Finalization



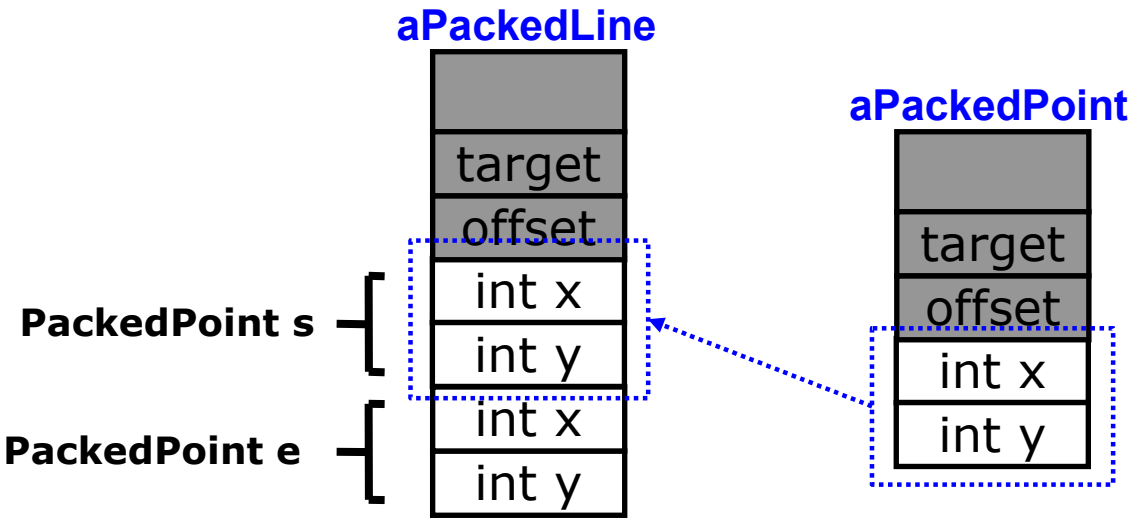
Nested Data Structures

```
aPackedLine.s = aPackedPoint;
```



Nested Data Structures

```
aPackedLine.s := aPackedPoint;
```



- Base types **do** share the same assignment operator
- Helps convey `aPackedLine == anotherPackedLine` as meaningless

Field Initialization

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

    PackedPoint(int x, int y) { … }
}

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

    PackedLine(int sx, int sy, int ex, int ey) { … }
}
```

No no-argument constructor

Implicitly instantiates PackedPoint objects for s & e fields

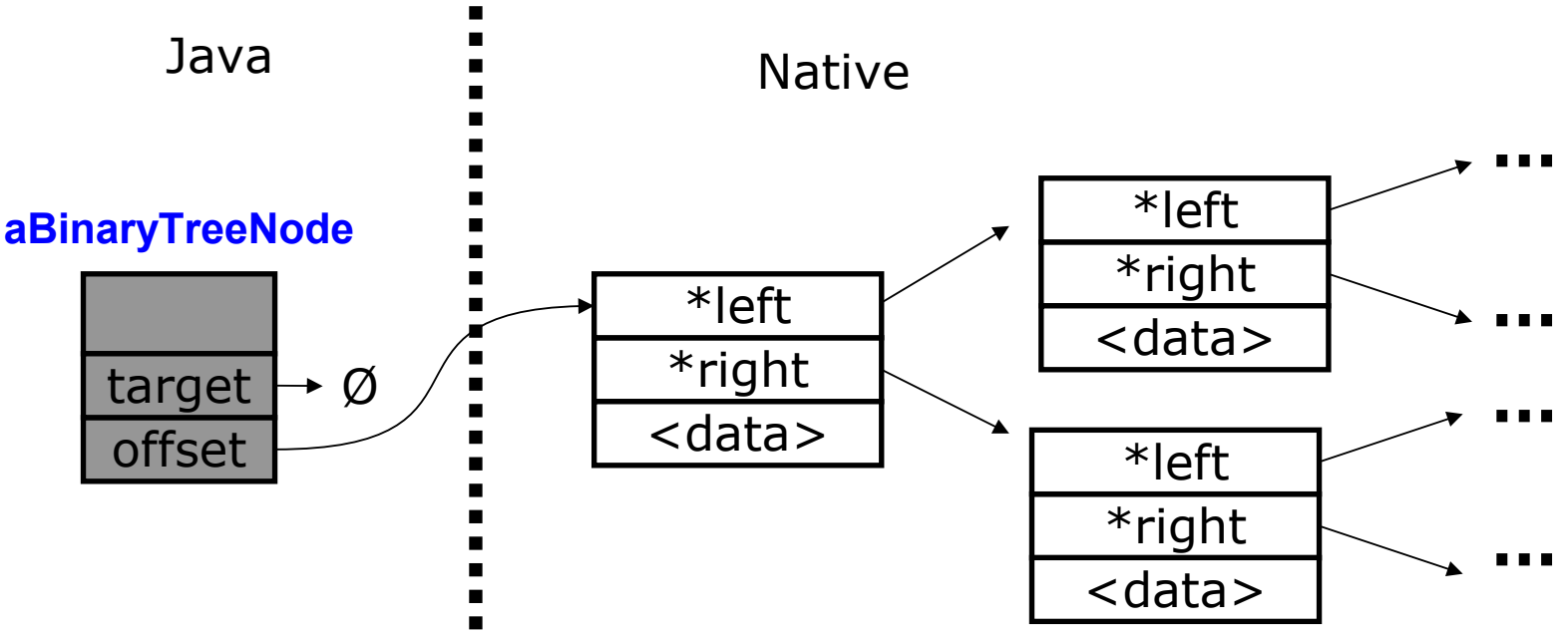
Field Initialization

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

    void init(int x, int y) {
        this.x = x;
        this.y = y;
    }

    PackedPoint(int x, int y) { … }
}

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

    PackedLine(int sx, int sy, int ex, int ey) {
        s.init(sx, sy);
        e.init(ex, ey);
    }
}
```

Advanced

Modeling Native Data Pointers

```
struct BinaryTreeNode {
    struct BinaryTreeNode* left;
    struct BinaryTreeNode* right;
    // data
}
```

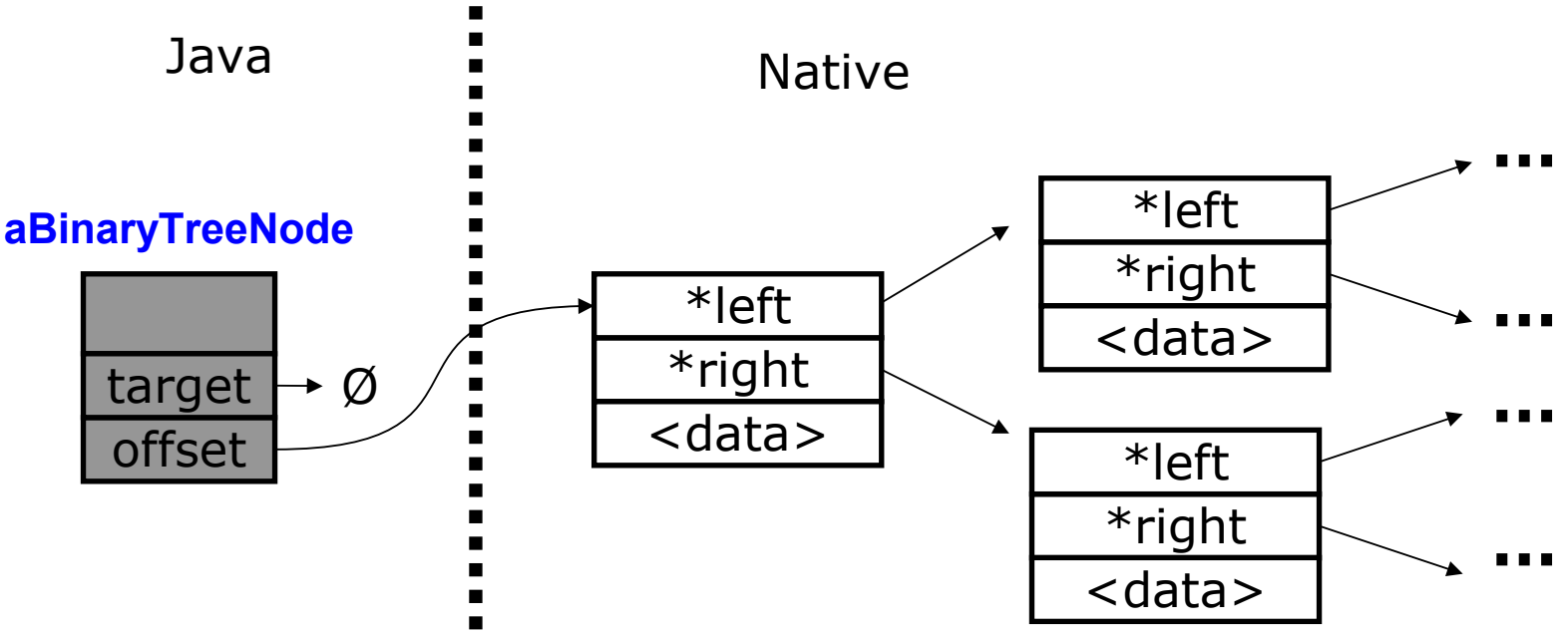


Modeling Native Data Pointers

?

aBinaryTreeNode.right

```
struct BinaryTreeNode {
    struct BinaryTreeNode* left;
    struct BinaryTreeNode* right;
    // data
}
```

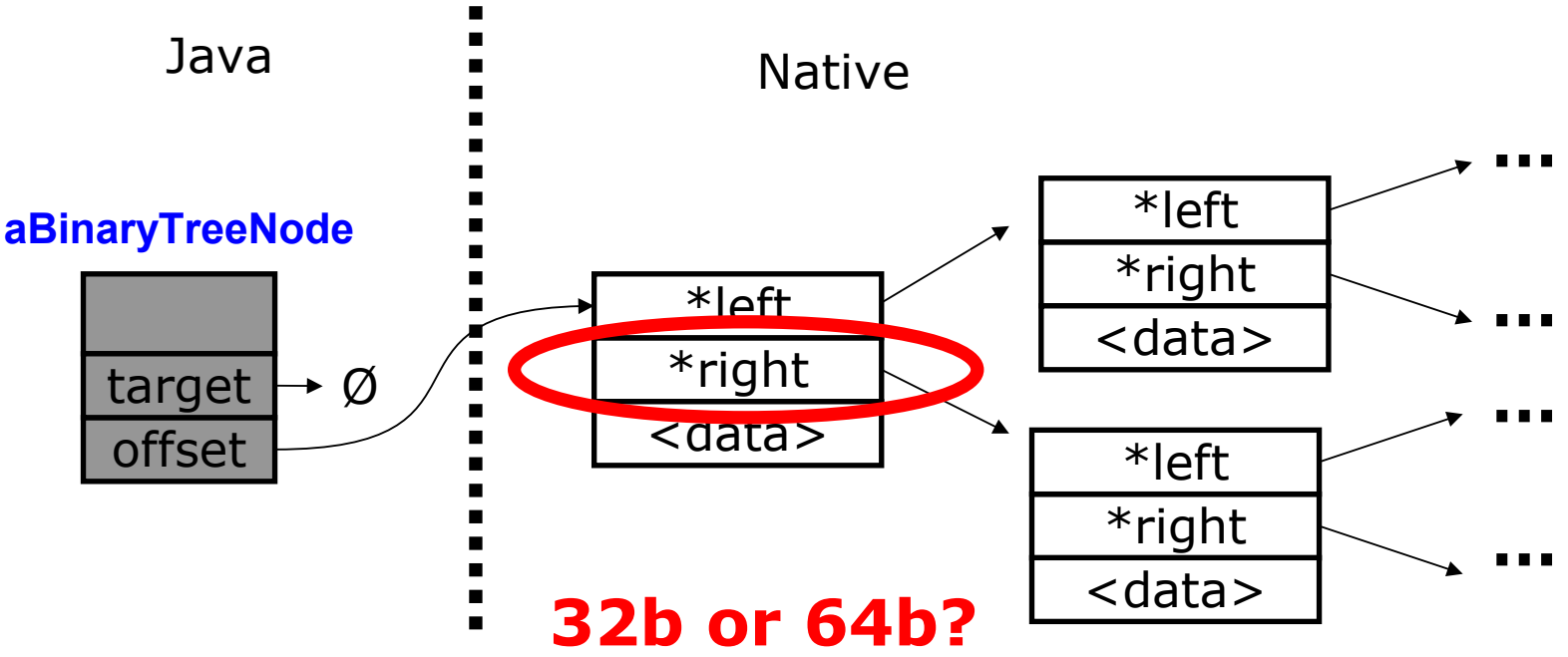


Modeling Native Data Pointers

?

aBinaryTreeNode.right

```
struct BinaryTreeNode {
    struct BinaryTreeNode* left;
    struct BinaryTreeNode* right;
    // data
}
```

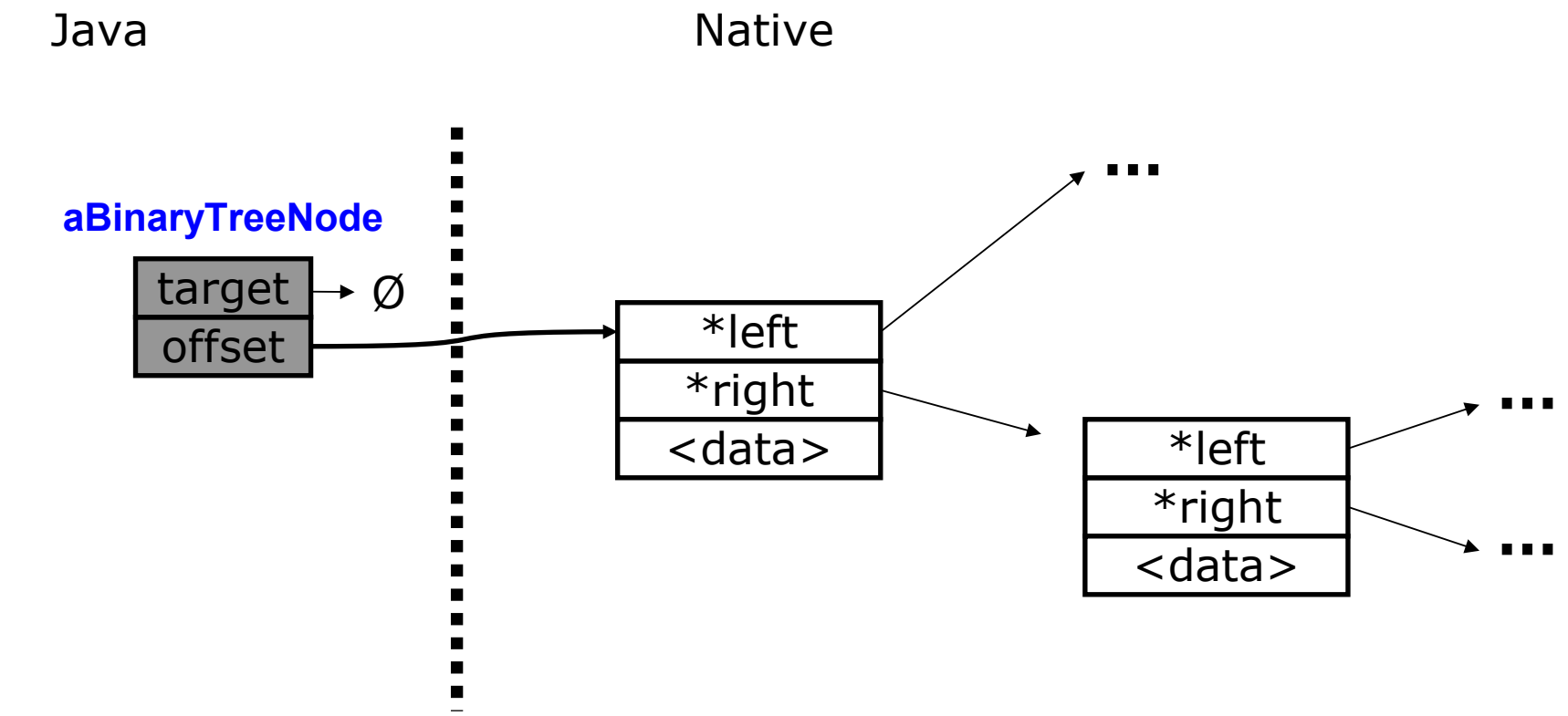


Modeling Native Data Pointers

```
@Packed
class BinaryTreeNode extends PackedObject {
    @NativePointer BinaryTreeNode left;
    @NativePointer BinaryTreeNode right;
    // data
}
```

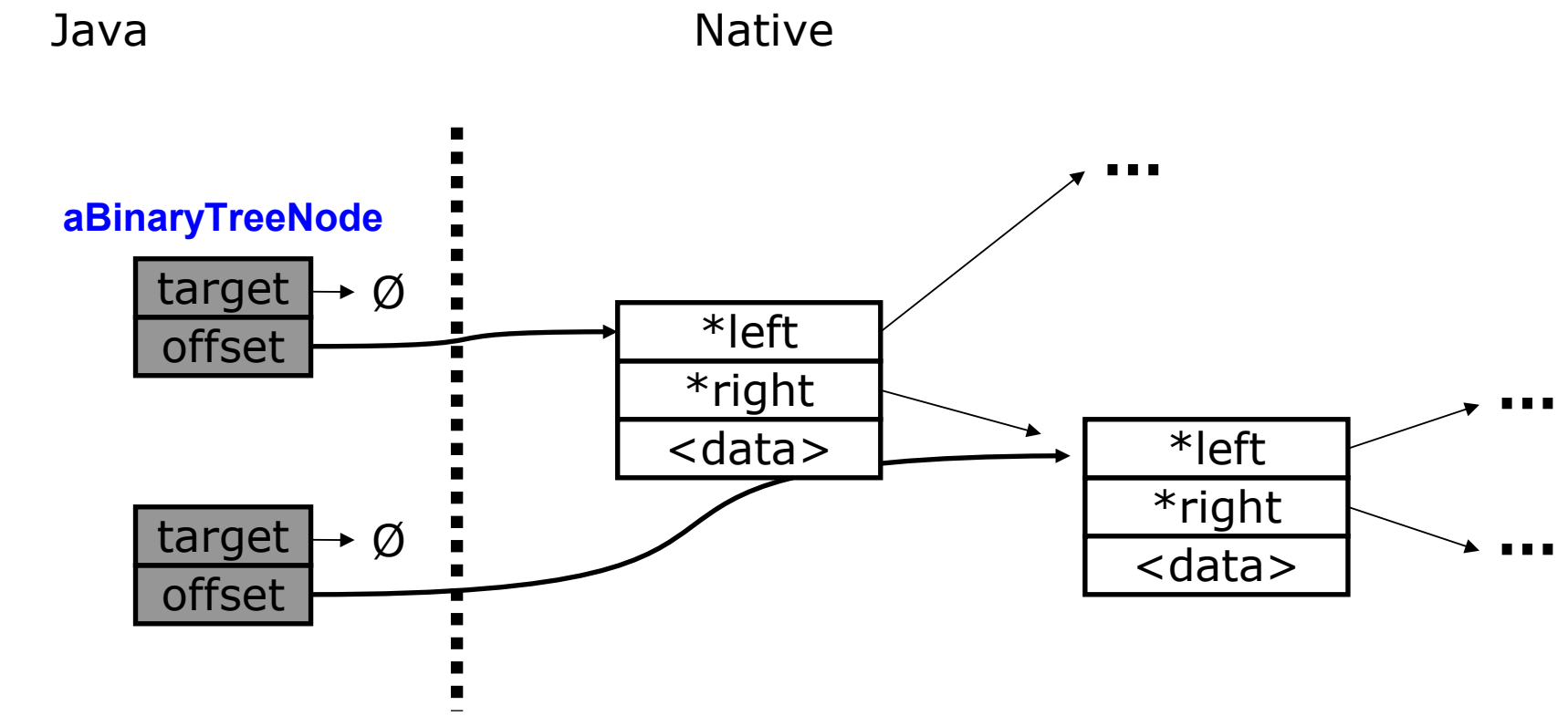
- Annotation to mark a field as a native pointer (rather than a Java one)
- Enhance `getfield` / `putfield` to recognize
- Restrict for security reasons
- Unmanaged pointers (no GC involvement)

Modeling Native Data Pointers




```
aBinaryTreeNode.right
```

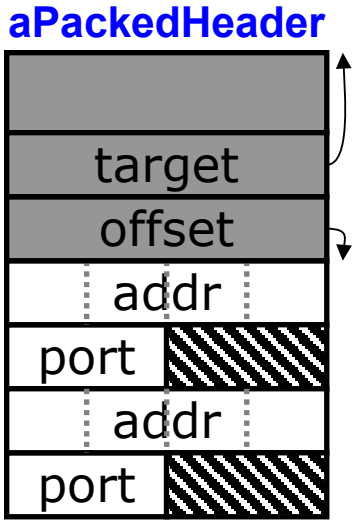
Modeling Native Data Pointers



`aBinaryTreeNode.right`

Alignment

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

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



Alignment

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@Packed
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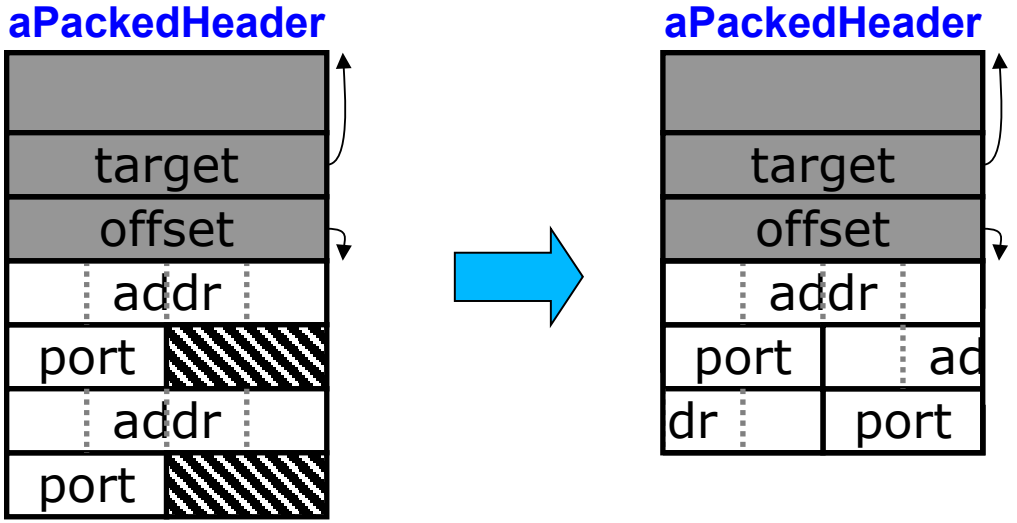
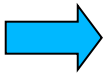


- Which is the correct default behavior?
- How do you get the alternate if that's what you want?

Alignment

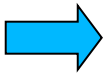
```
class A {
    int i;
    short s;
    short padding; // align
    long l;
}
```



```
class A {
    int i;
    short s;
    @Align long l;
}
```

Alignment

```
class A {
    int i;
    short s;
    short padding; // align
    long l;
}
```



```
class A {
    int i;
    short s;
    @Align long l;
}
```

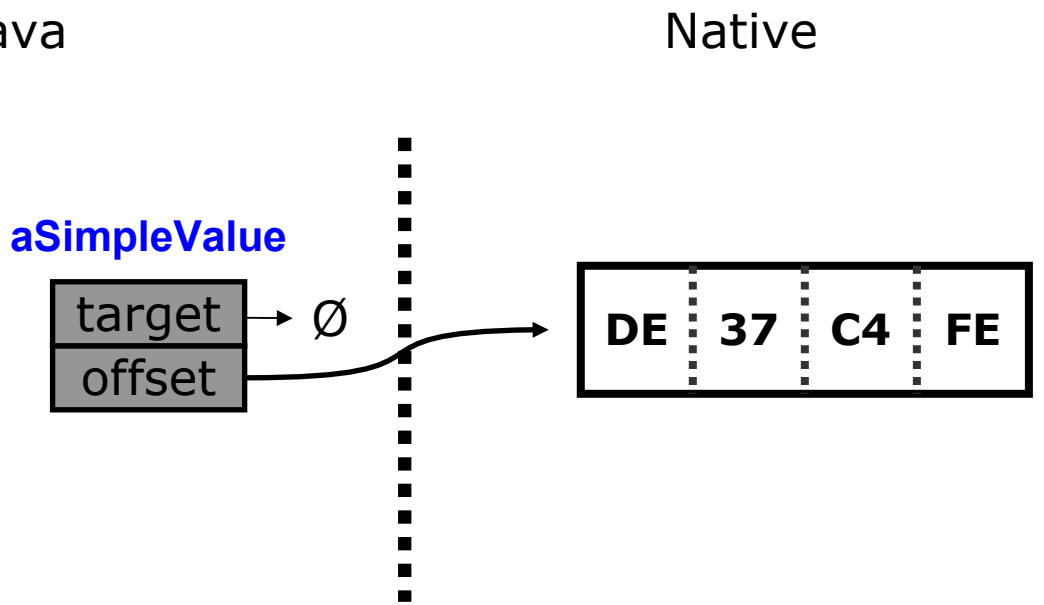
- Padding isn't quite right in the context of nested structures…

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

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

Endian

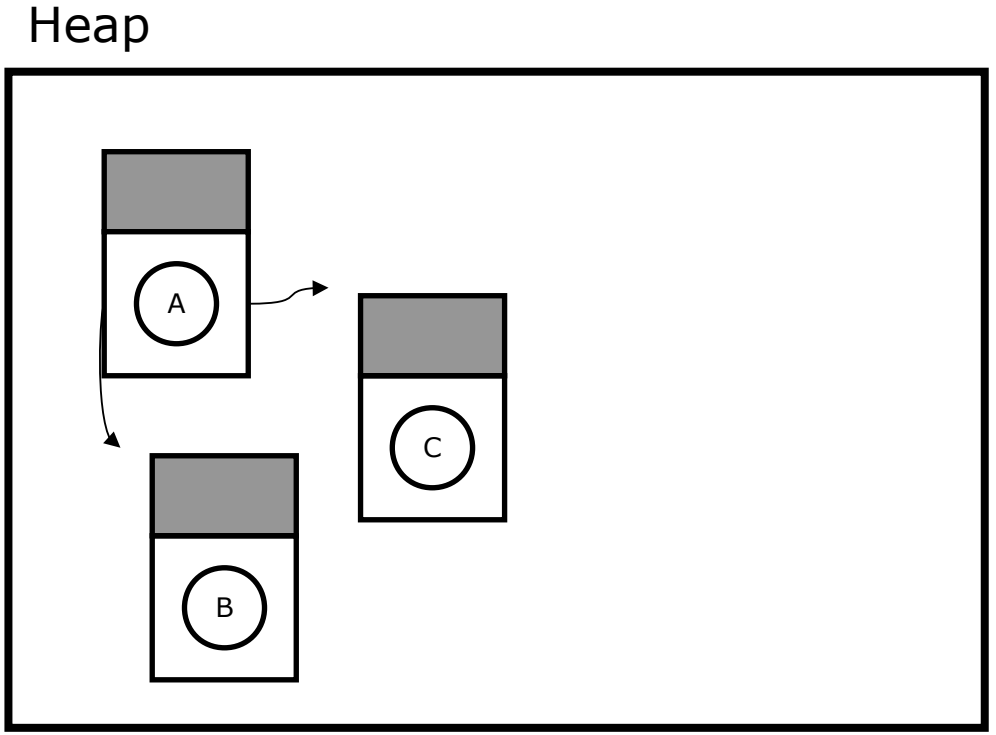
```
@Packed
final class SimpleValue extends PackedObject {
      int value;
}
```



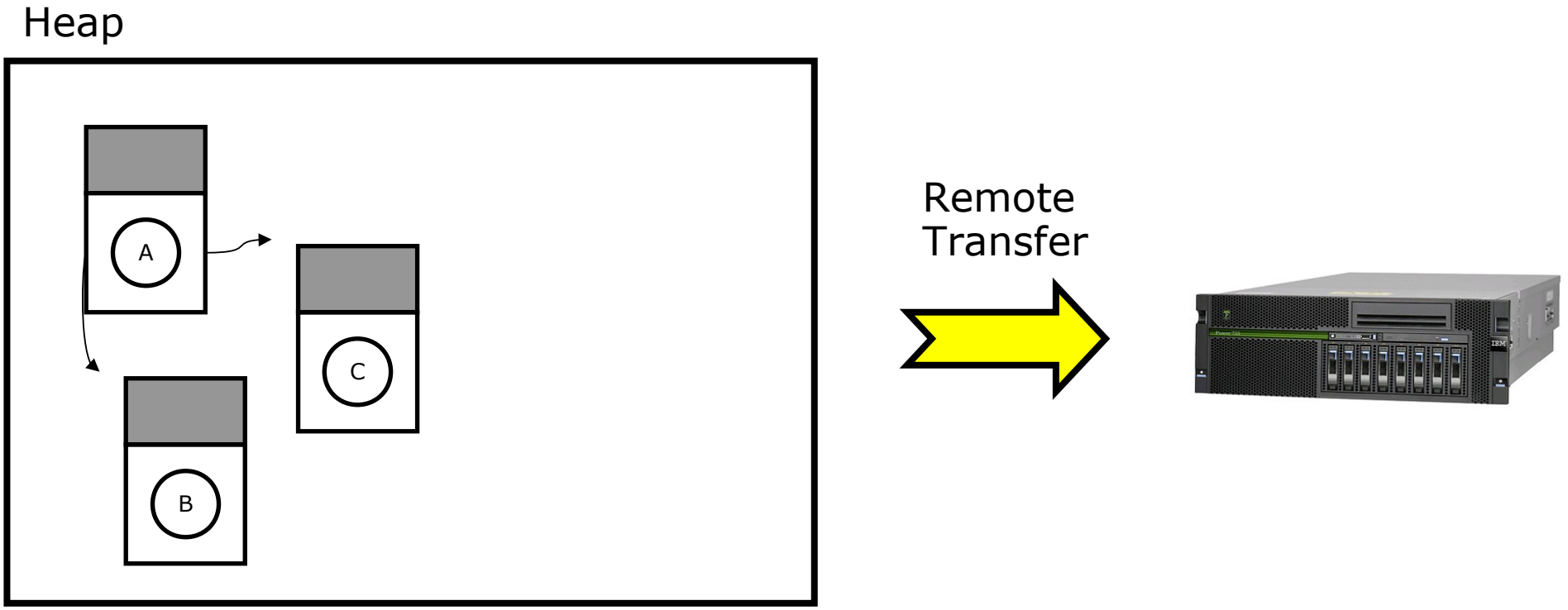
- Provide a field annotation `@BigEndian` (and `@LittleEndian`)

Possibilities

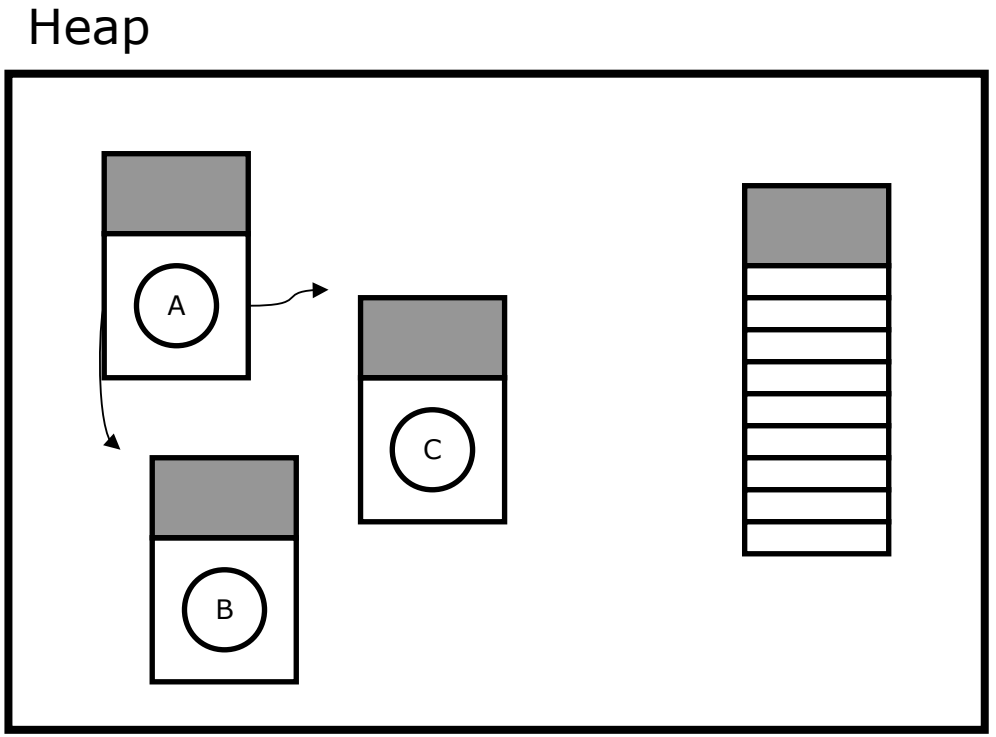
Let's look at transferring data



Let's look at transferring data

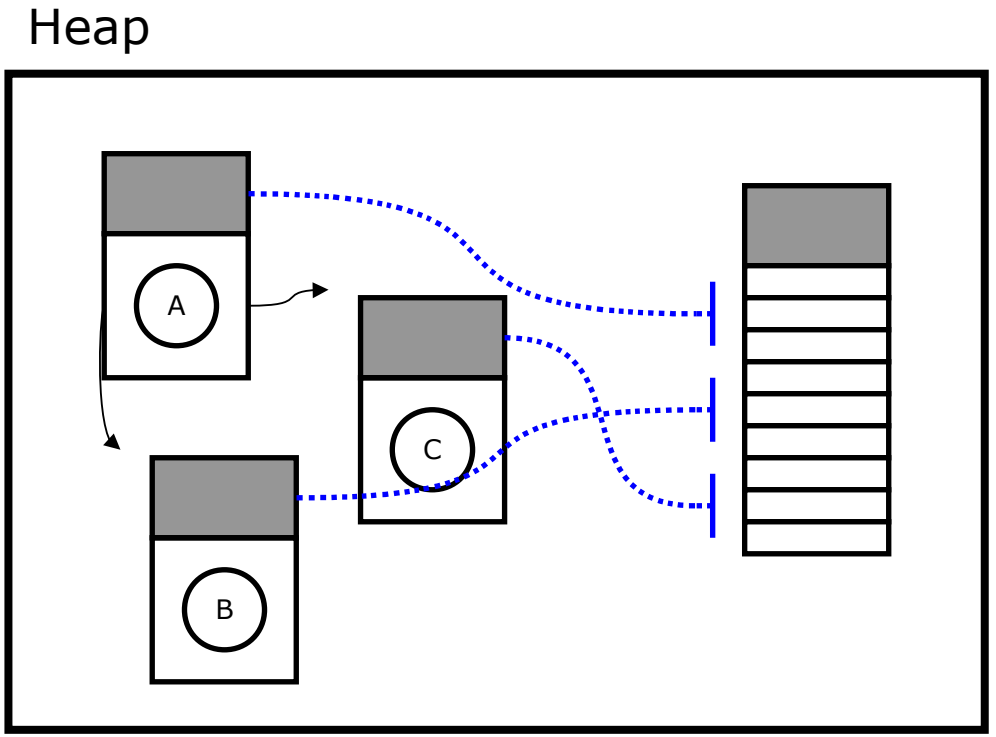


Let's look at transferring data



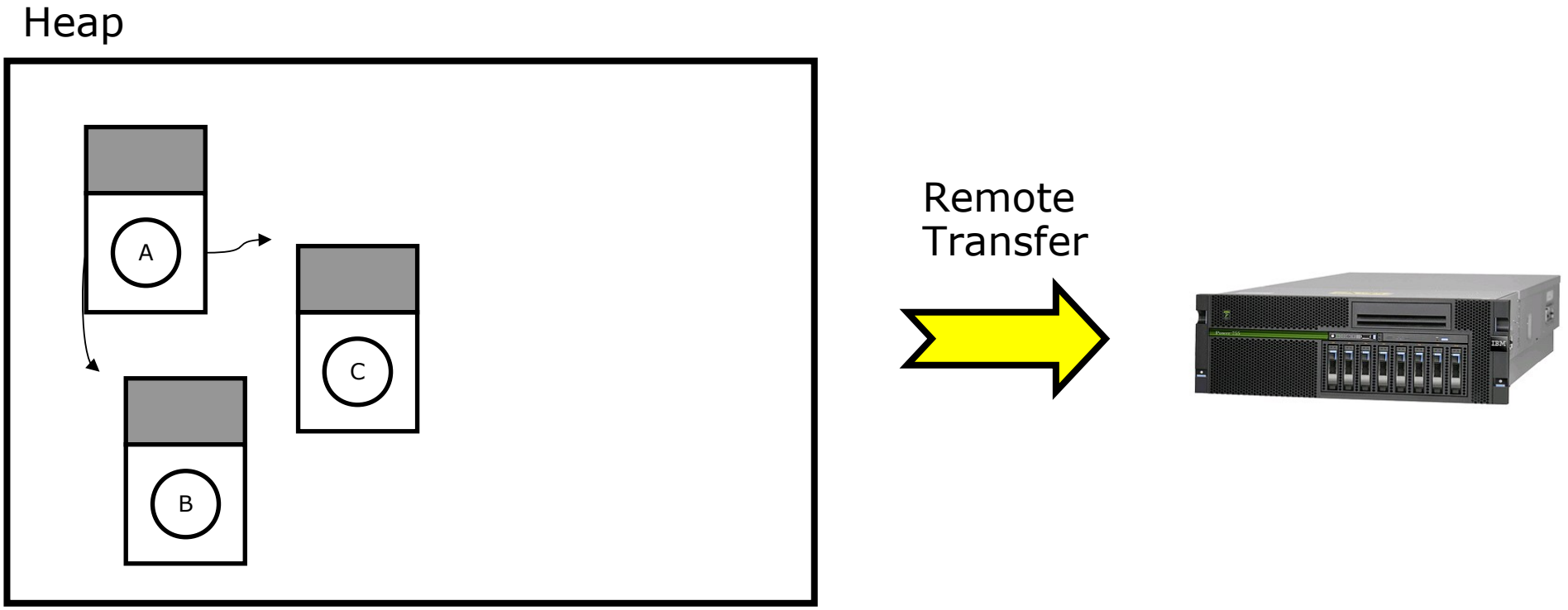
Remote Transfer

Let's look at transferring data



Remote Transfer

PackedObjects could help…



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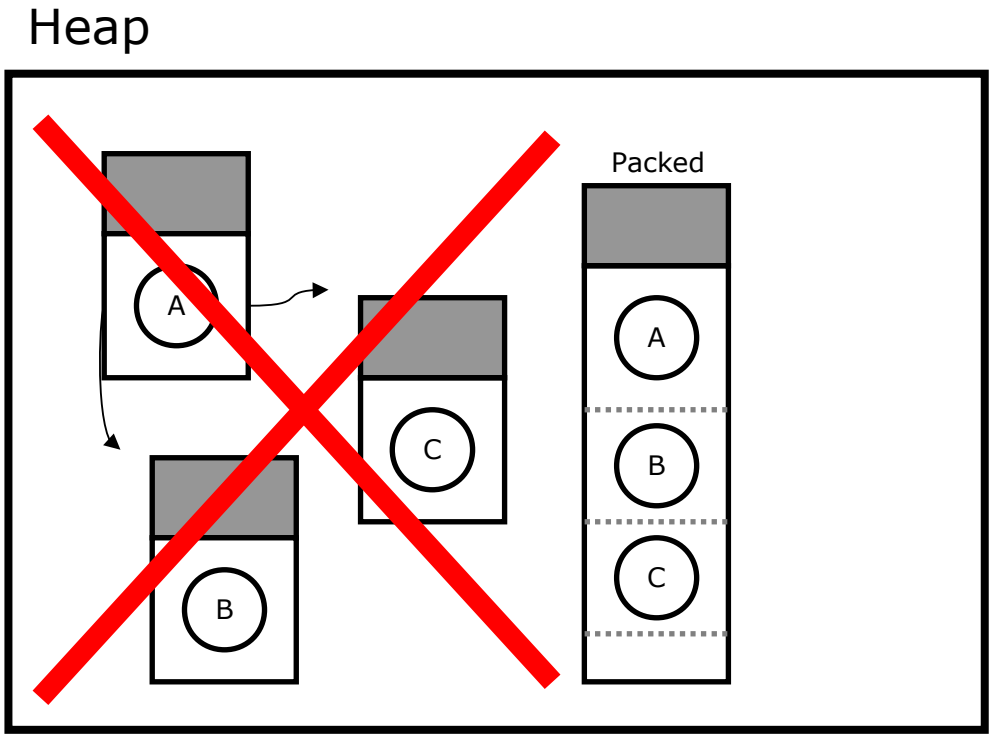
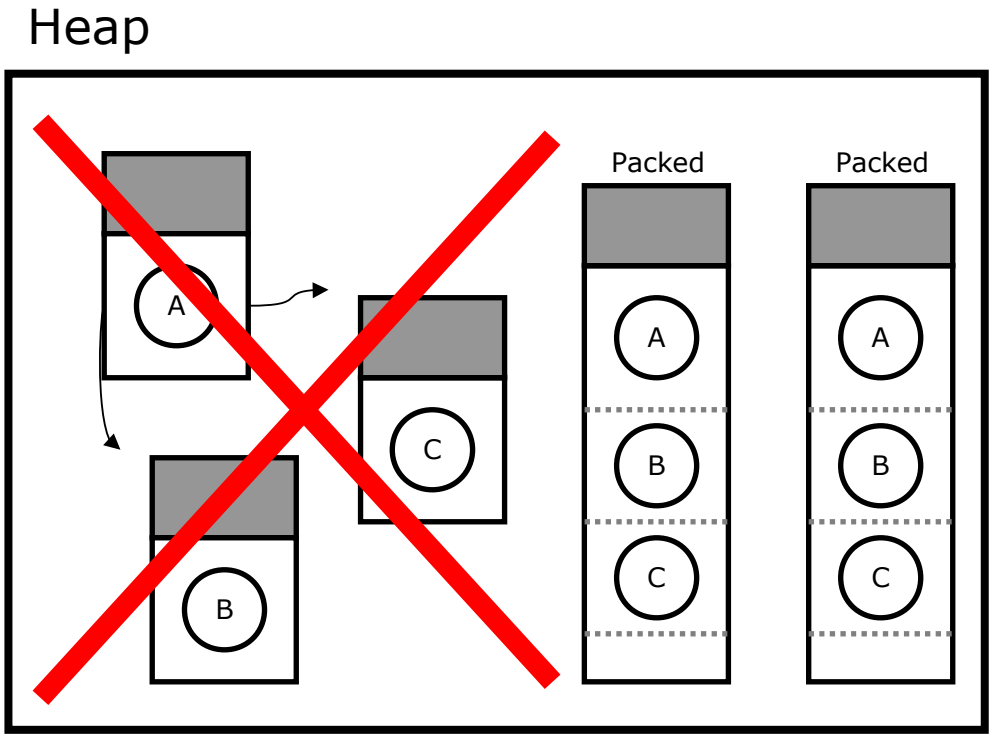


Remote Transfer

PackedObjects could help…

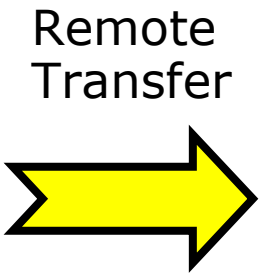


Remote Transfer

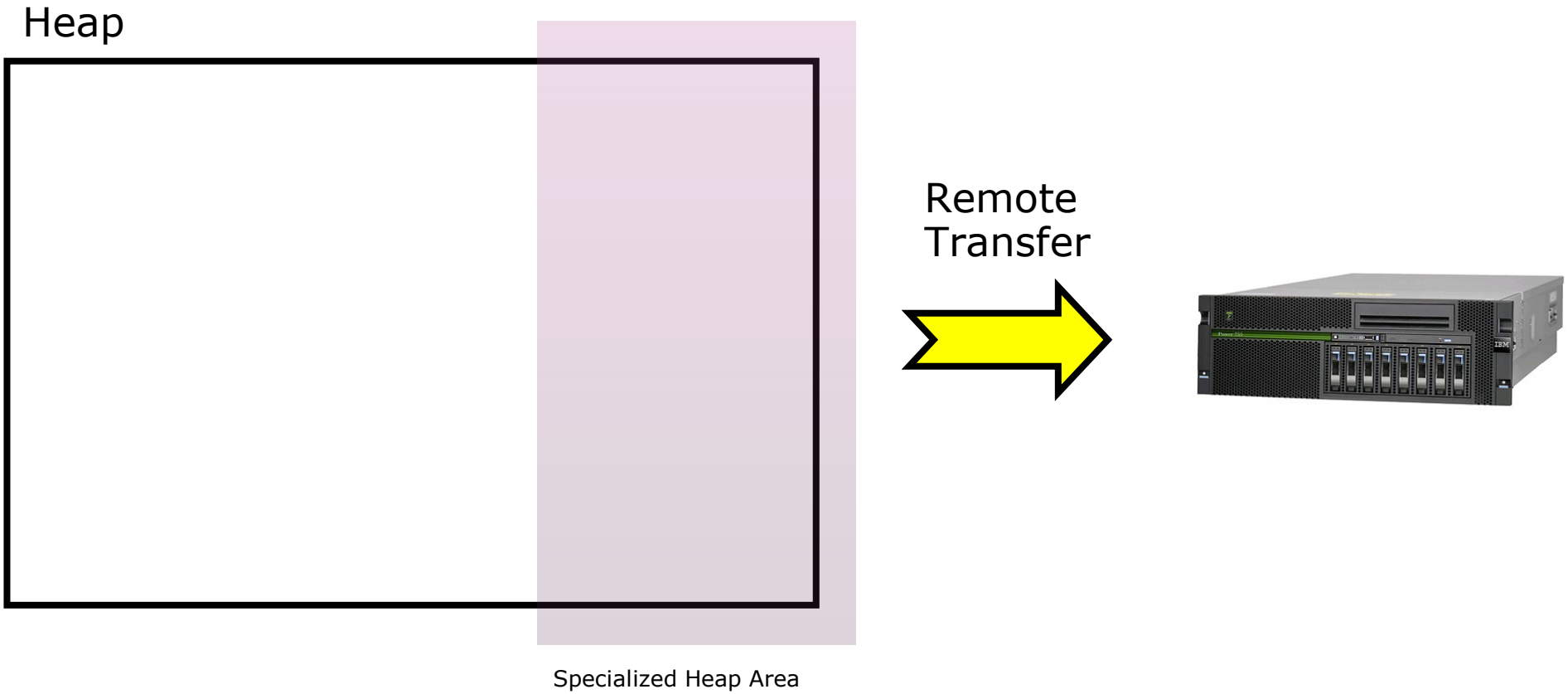
Making the data transfer easier…

Heap

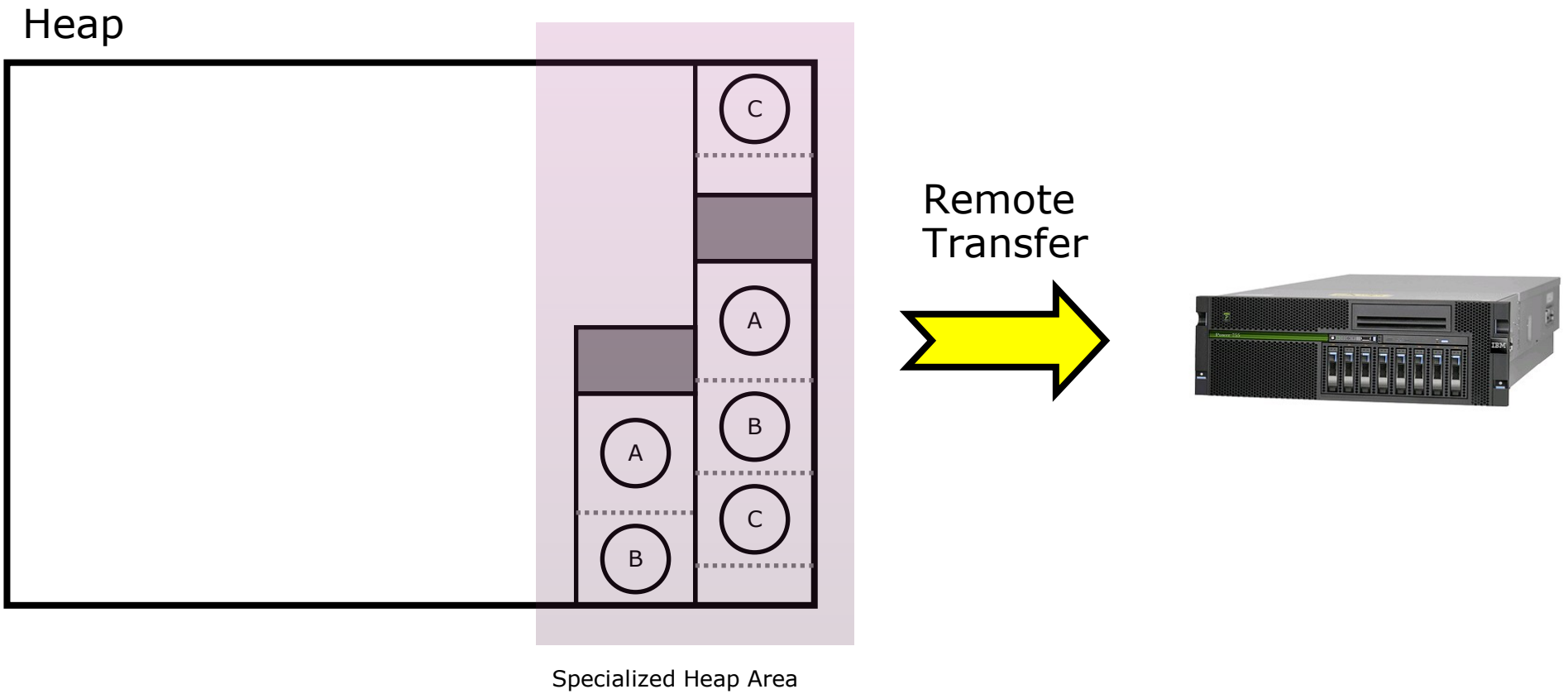
Remote
Transfer



Making the data transfer easier…

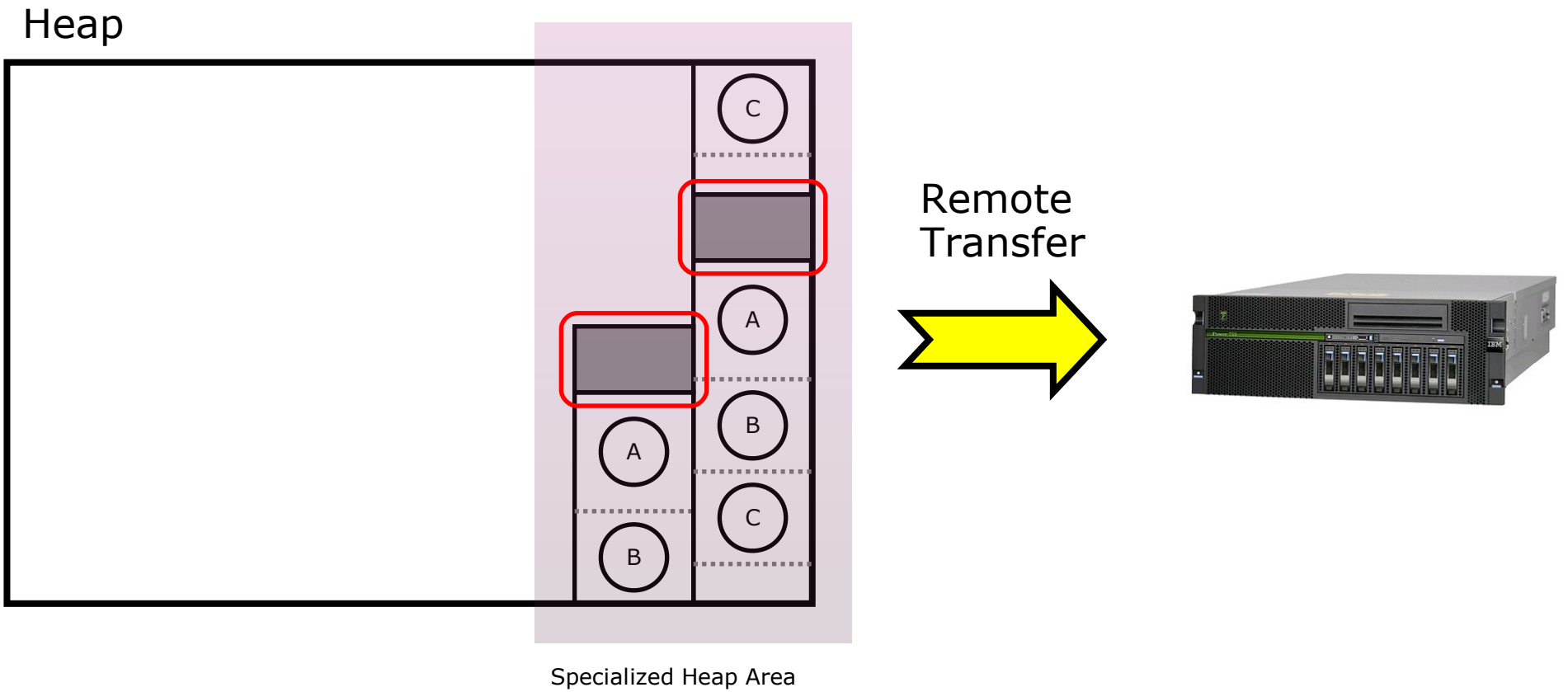


Making the data transfer easier…



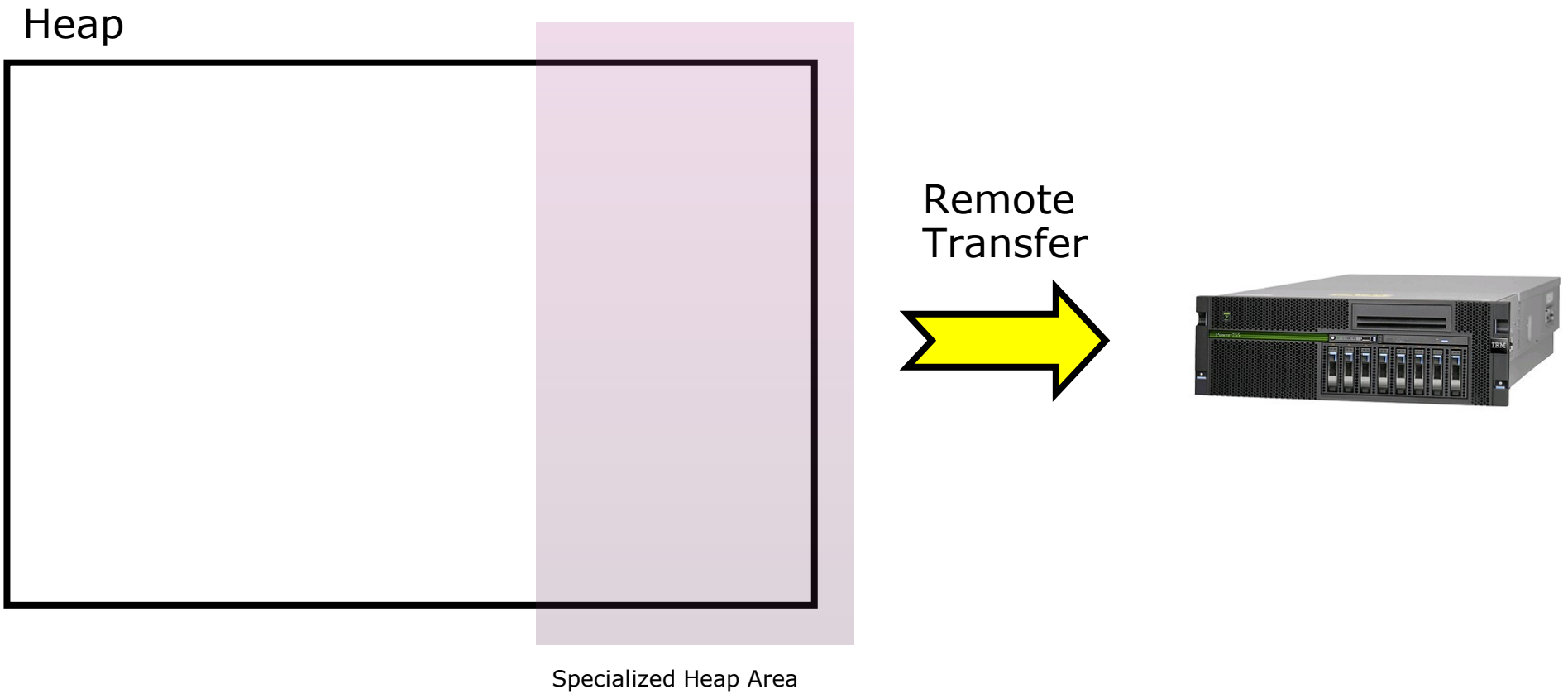
Specialized Heap Area

Making the data transfer easier…

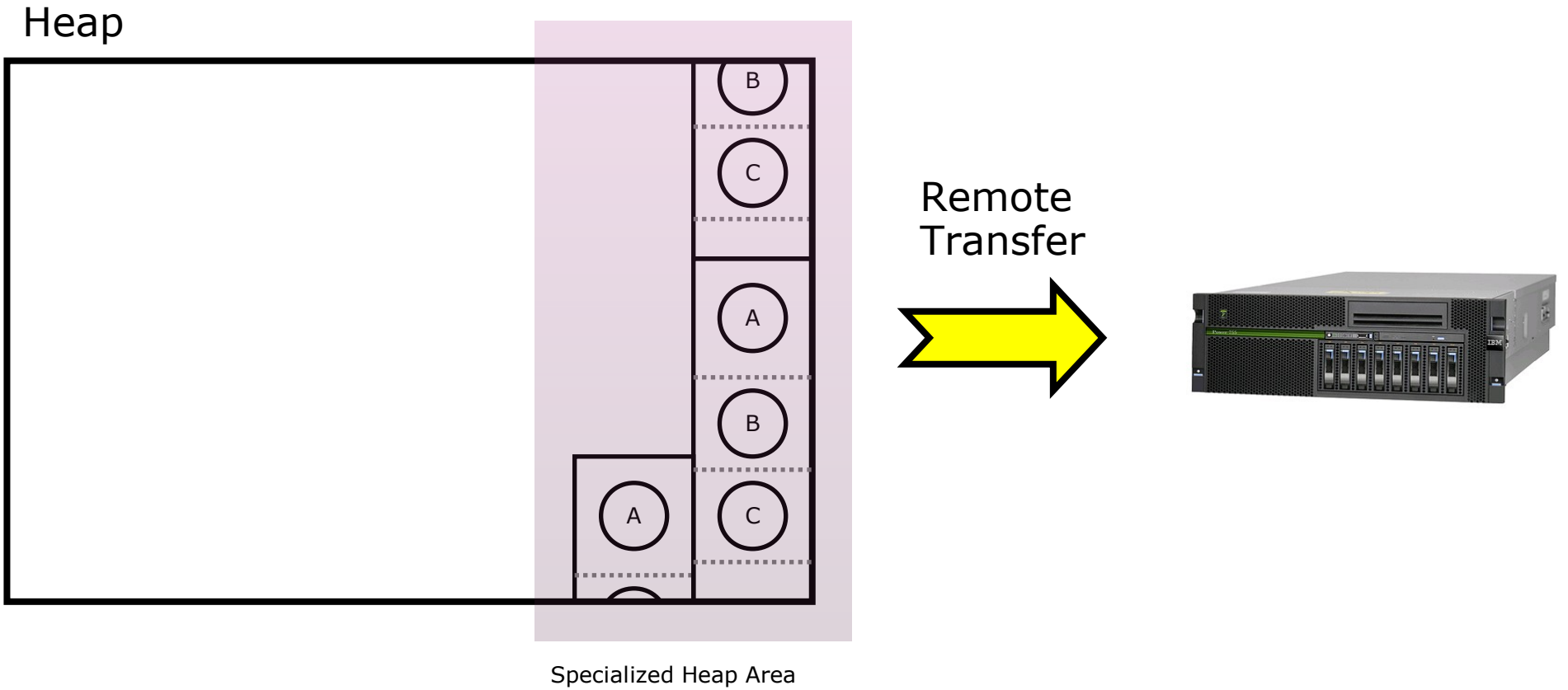


Specialized Heap Area

Making the data transfer seamless

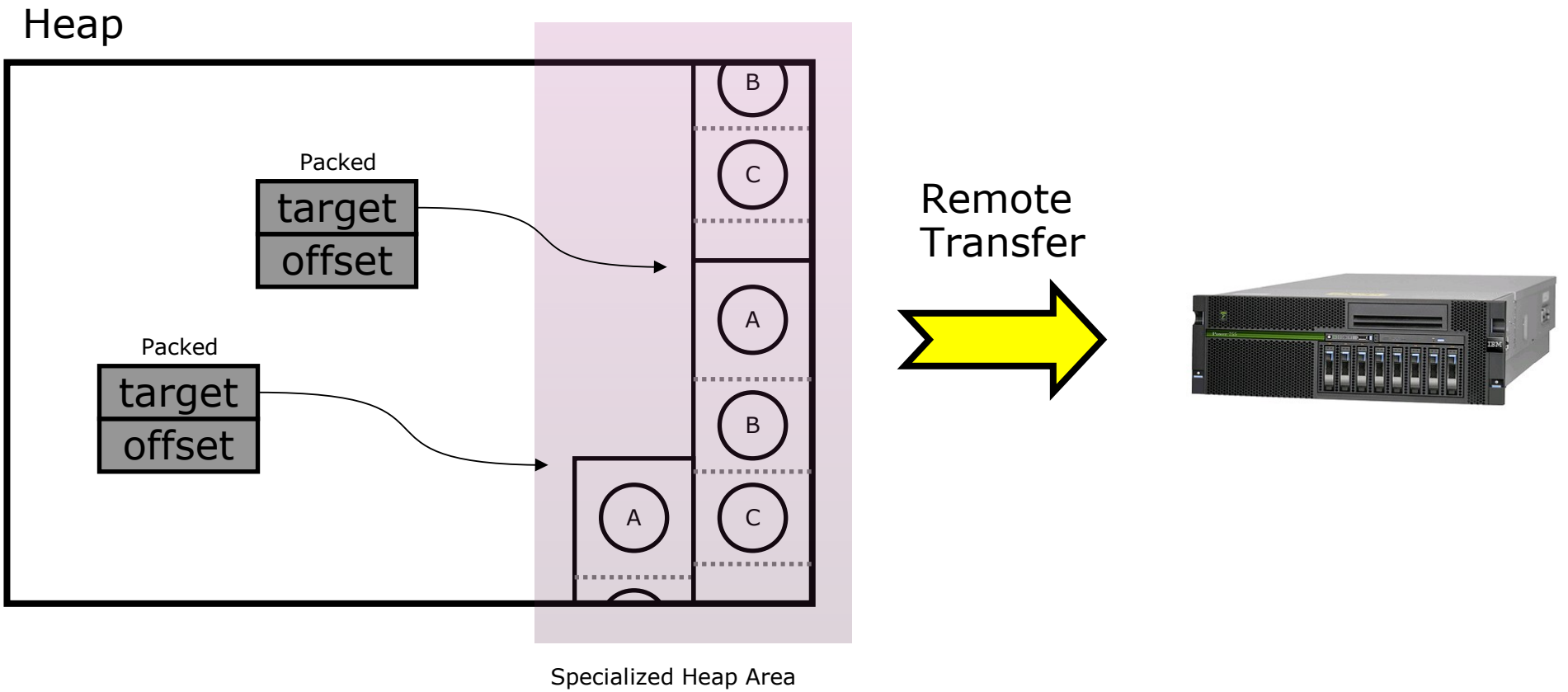


Making the data transfer seamless



Specialized Heap Area

Making the data transfer seamless



Questions?

References

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