Netty

One Framework to rule them all….

- Leading the Netty Project
- Apache Cassandra MVP 2016 - 2017
- Author of Netty in Action
- Apache Software Foundation
- Eclipse Foundation

A long journey

Some background

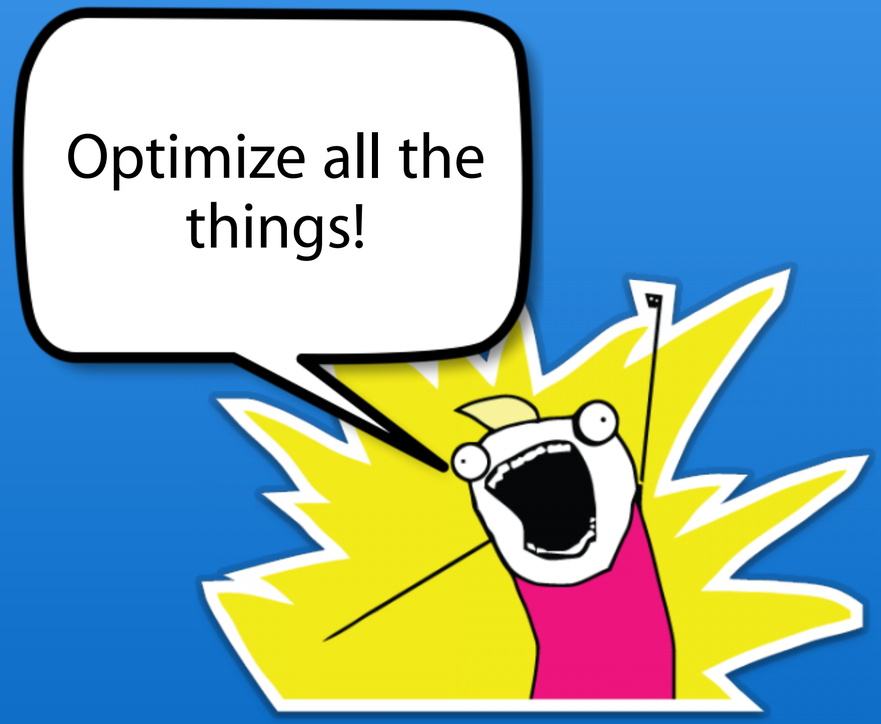
- Netty 3.0.0.GA released in 2008
- Netty 4.0.0.Final released in 2013
- Netty 4.1.0.Final released in 2016
- one of the most used Network Framework for the JVM
- founded by Trustin Lee <3
- JBoss Project first, then independent
- very vibrant community

Netty 3.x

- too much garbage
- too many memory copies
- no good memory pool included
- not optimized for Linux based OS
- threading model not easy to reason about

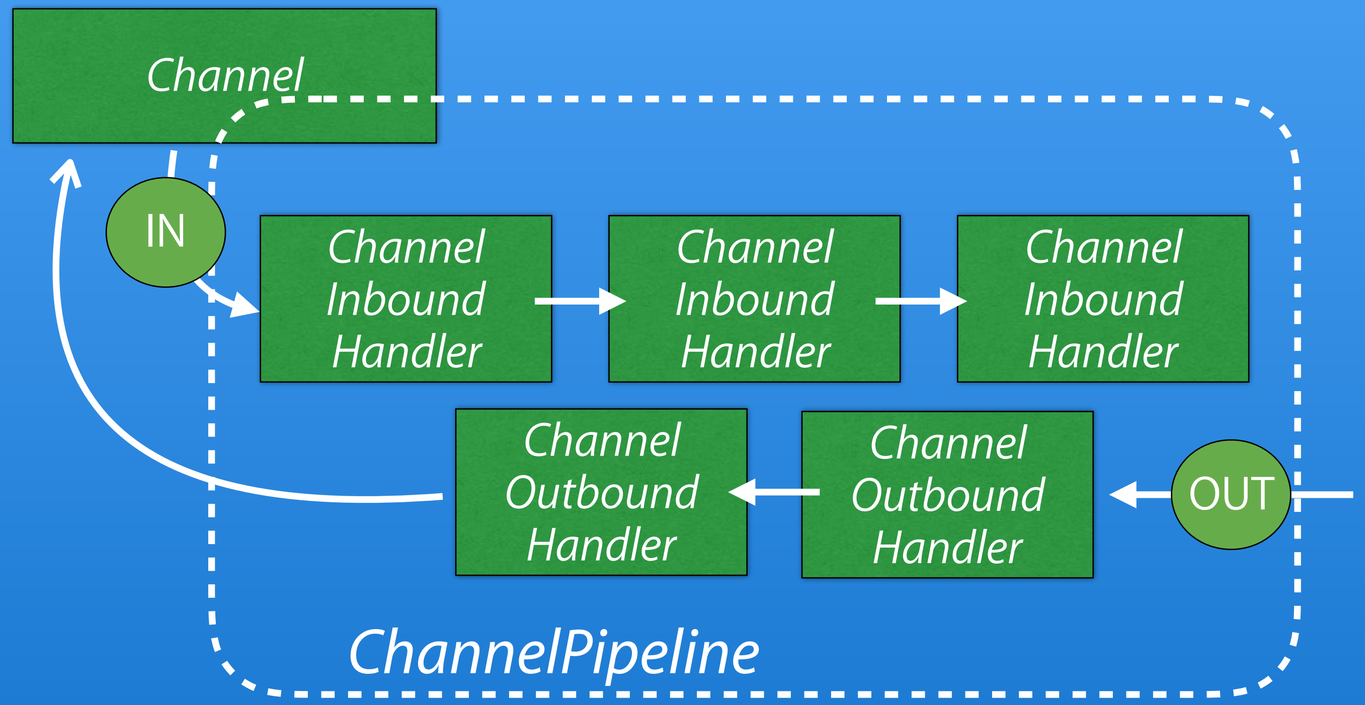
Netty 4.x now!

- create less garbage, less GC
- optimized for Linux based OS + Linux only features
- high performance buffer pool based on jemalloc paper
- well defined, easy to use threading model



And there is more too come….

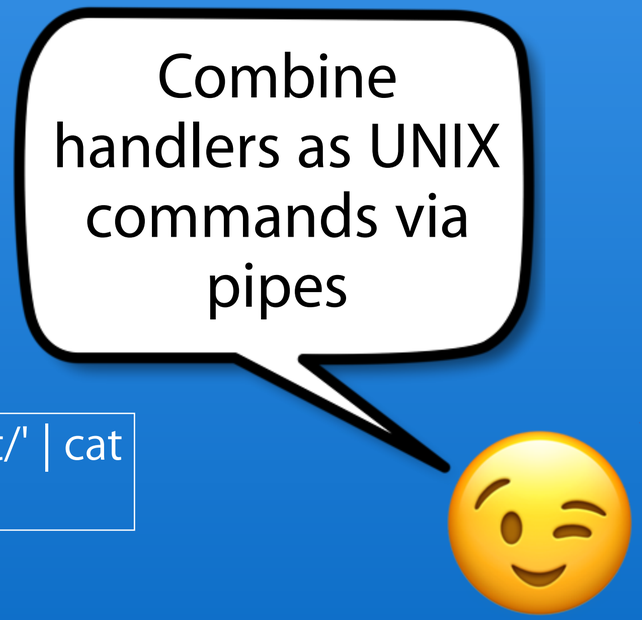
ChannelPipeline



- Inbound events -> *ChannelInboundHandler*
- Outbound events -> *ChannelOutboundHandler*

ChannelPipeline

- Interceptor pattern
- allows to add building-blocks (*ChannelHandler*) on the fly that transforms data or react on events.



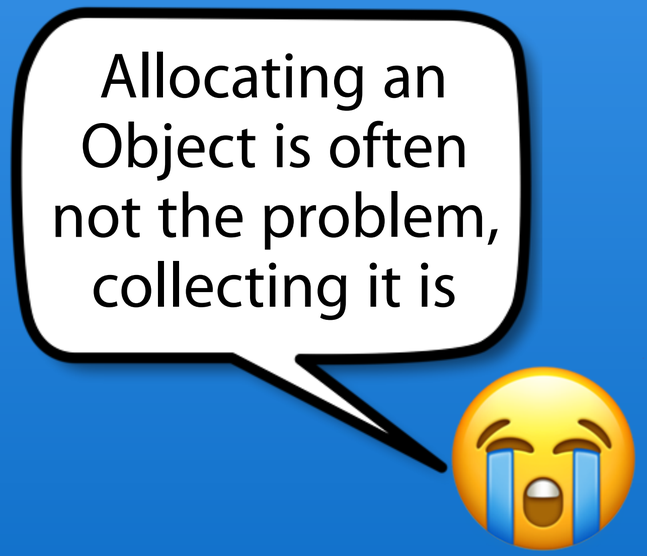

```
$ echo "Netty is slow...." | sed -e 's/slow/fast/' | cat
Netty is fast....
```

Too much garbage

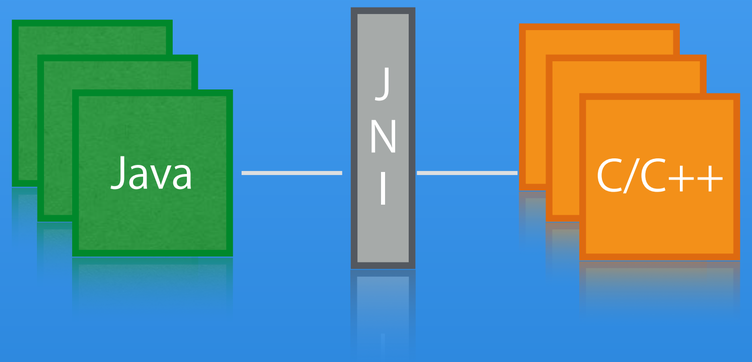
Run collector ….run!

Reduce Garbage

- eliminate GC by replace event objects with direct method invocations
- light-weight object pool for heavily allocated objects (like *ByteBuf* instances)



JNI to the rescue



- optimized transport for Linux only
- supports Linux specific features
- directly operate on pointers for buffers
- synchronization optimized for Netty's threading model

Native Transport
epoll based high-performance transport

NIO Transport

```
Bootstrap bootstrap = new Bootstrap().group(
        new NioEventLoopGroup());
bootstrap.channel(NioSocketChannel.class);
```

Native Transport

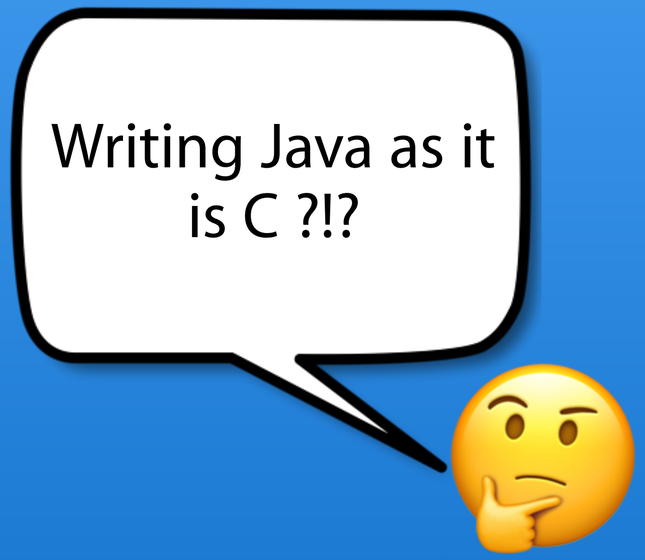
```
Bootstrap bootstrap = new Bootstrap().group(
        new EpollEventLoopGroup());
bootstrap.channel(EpollSocketChannel.class);
```

- less GC pressure due less *Objects*
- advanced features
  - *SO_REUSEPORT*
  - *TCP_CORK*
  - *TCP_NOTSENT_LOWAT*
  - *TCP_FASTOPEN*
  - *TCP_INFO*
- *LT and ET*
- Unix Domain Sockets

Buffers

Performance vs Complexity

ByteBuf

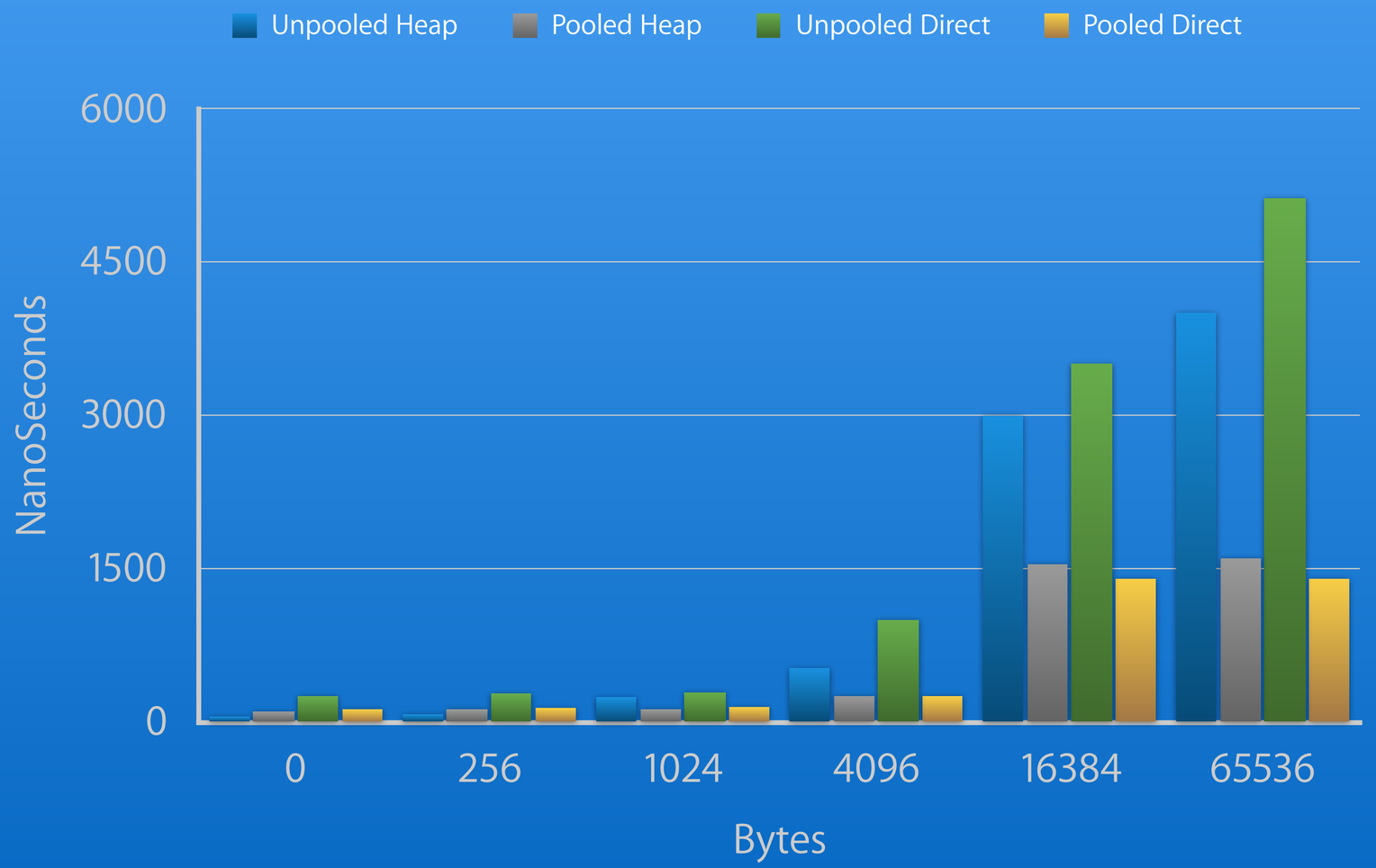


- *ByteBufs* are reference counted (huh!?!?)
- pooling is used by default
- provide *LeakDetector* which helps detecting *ByteBuf* leaks
- direct memory are used by default
- provide special abstractions to iterate over bytes to reduce branching / range-checks
- all buffers are dynamic and can grow

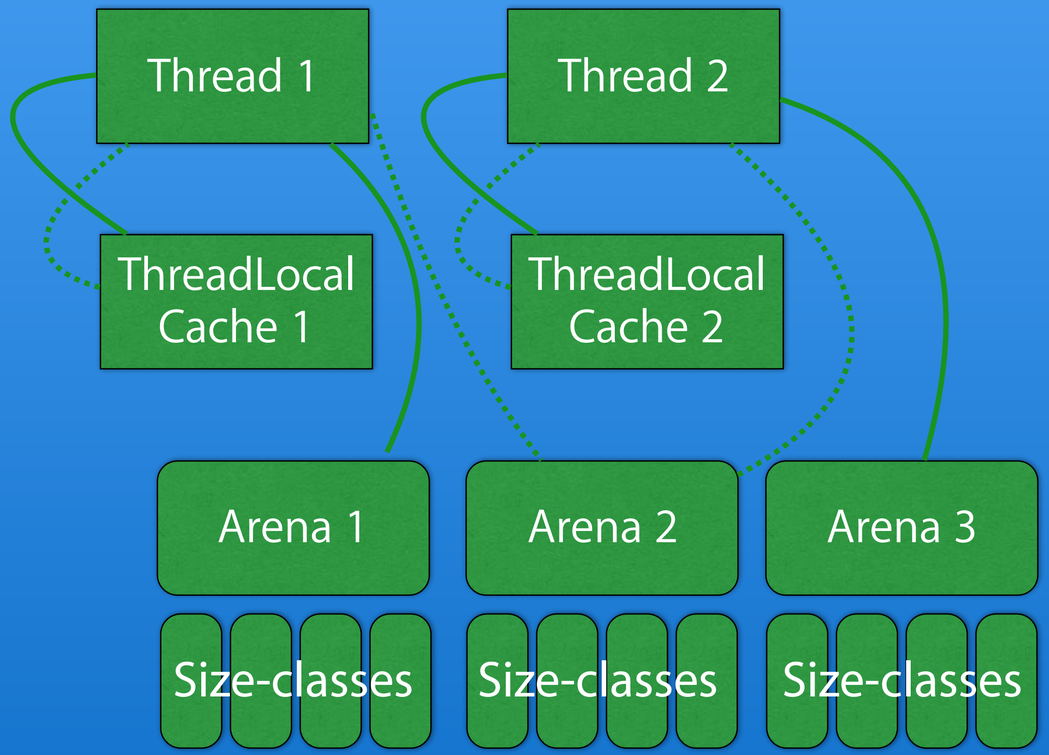
Buffer Pooling

Allocations are expensive

Allocation times



PooledByteBufAllocator

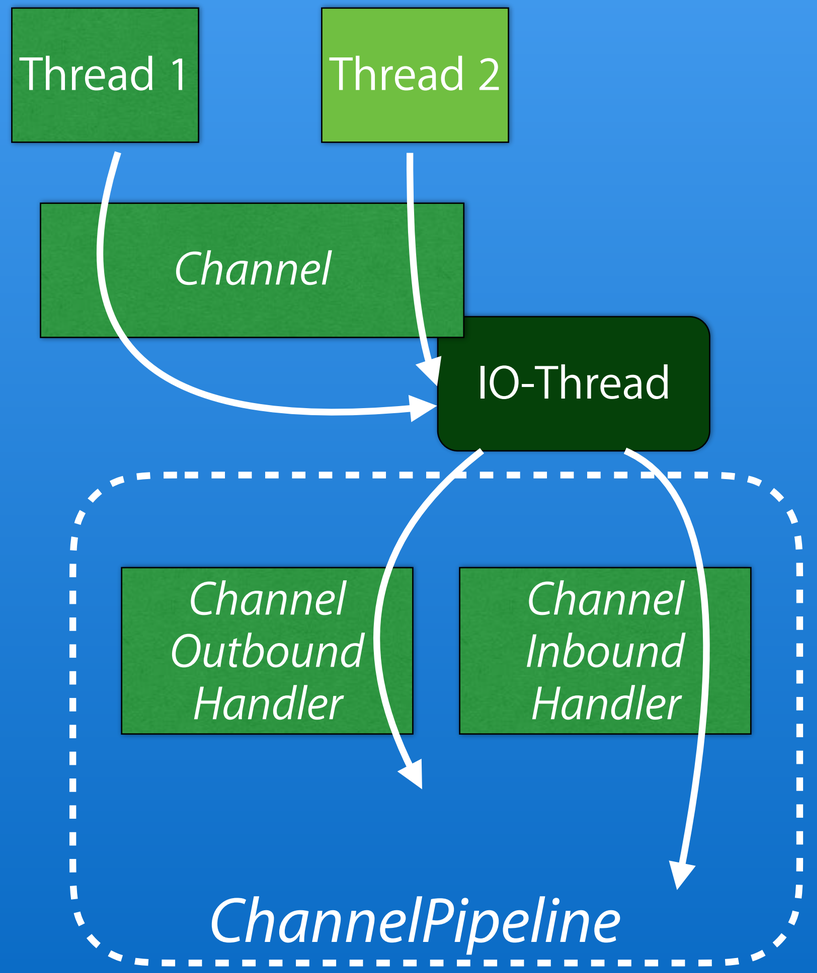


- based on jemalloc paper (3.x)
- *ThreadLocal* caches for lock-free allocation
- synchronize per Arena that holds the different chunks of memory
- different size classes
- reduce fragmentation

Threading Model

Writing multi-threaded applications is hard….

Threading-Model

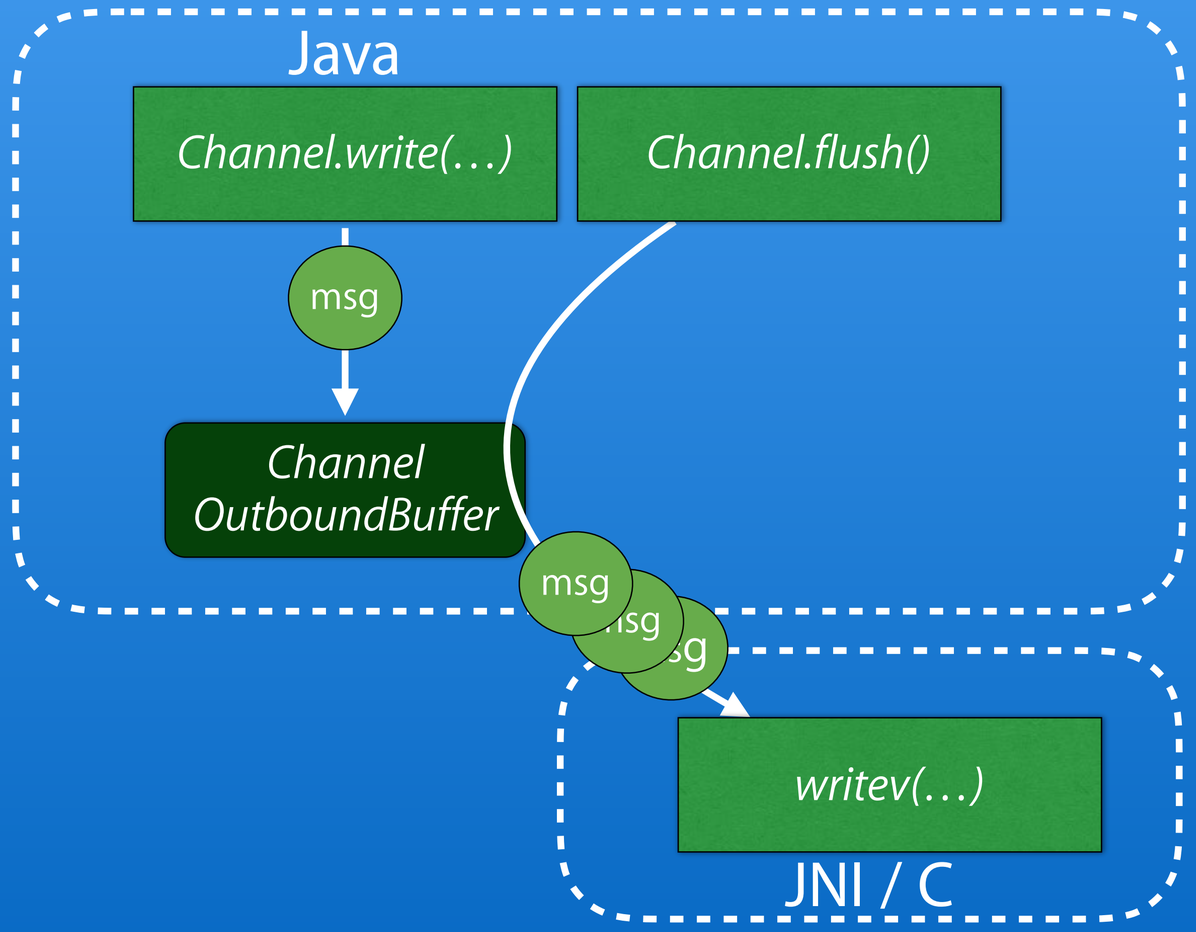


- all events / operations are done by the IO-Thread!
- eliminates the need of *synchronization* completly (as long as the handler is not shared!)
- writing single-threaded code FTW

Write Semantics

syscalls are expensive…

Write Semantics



- *Channel.write(…)* will only put messages in the *ChannelOutboundBuffer* once processed.
- *Channel.flush()* will flush everything in the *ChannelOutboundBuffer* and so call *writev(…)*.

Read Semantics

Fine grained control FTW

Read Semantics

```
while (i < messagesPerRead) {
   read(…);
}
```

- *ChannelConfig.setAutoRead(boolean)* to the rescue.
- *ChannelConfig.setMaxMessagesPerRead(int)* allows to limit max number of messages to read.
- *Channel.read()* allows to explicit trigger a read.
- *RecvByteBufAllocator* gives even more flexibility

IO - Threads

Never-ever block the IO-Thread!

EventLoop(Group)

```
for (;;) {
    waitForEventsOrTasks();
    processEvents();
    processTasks();
    processScheduledTasks();
}
```

- IO *Thread* abstracted as *EventLoop*
- easily share the same *EventLoop* between Server and Client
- be able to explicitly use same *EventLoop* for accepted connection and outbound connection (win for proxy applications!)
- **Bonus:** *EventLoop* is also a *ScheduledEventExecutor*

Work outside the IO-Thread

sometimes you need to block

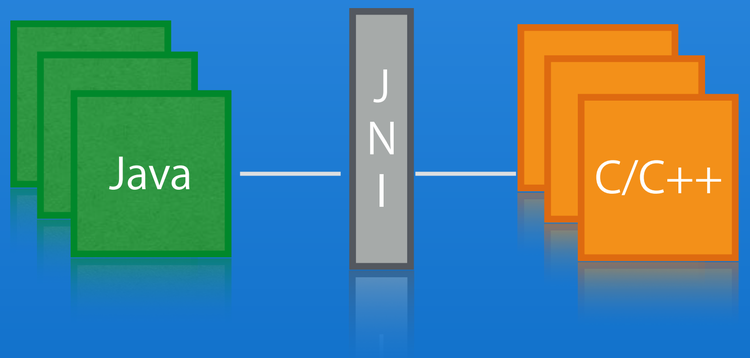
EventExecutor(Group)

```
ChannelPipeline pipeline = …;
pipeline.addLast(executorGroup,
    new ExecutionHandler(…));
```

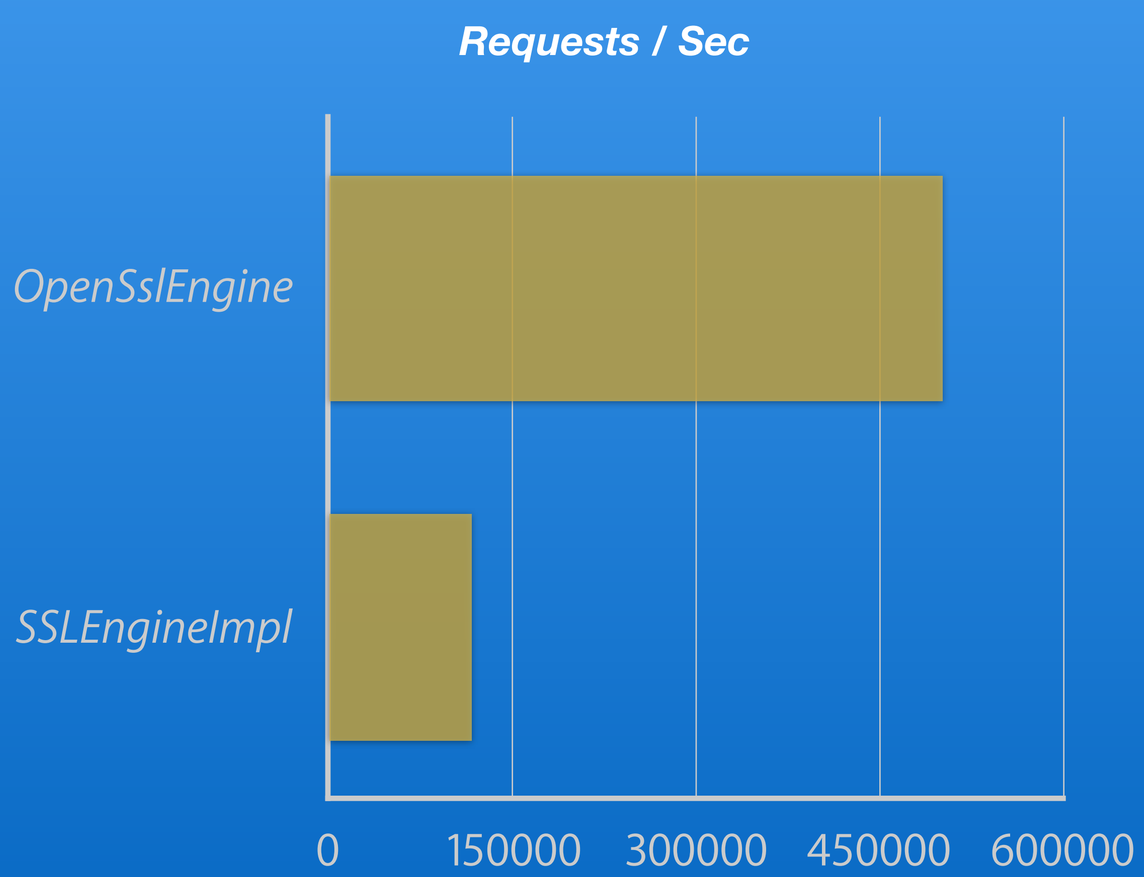
- part of the core itself
- adding *ChannelHandler* with an *EventExecutorGroup* will get the job done
- different *EventExecutorGroup* implementations for serial / non-serial executions.
- supports moving work to other *EventLoop*

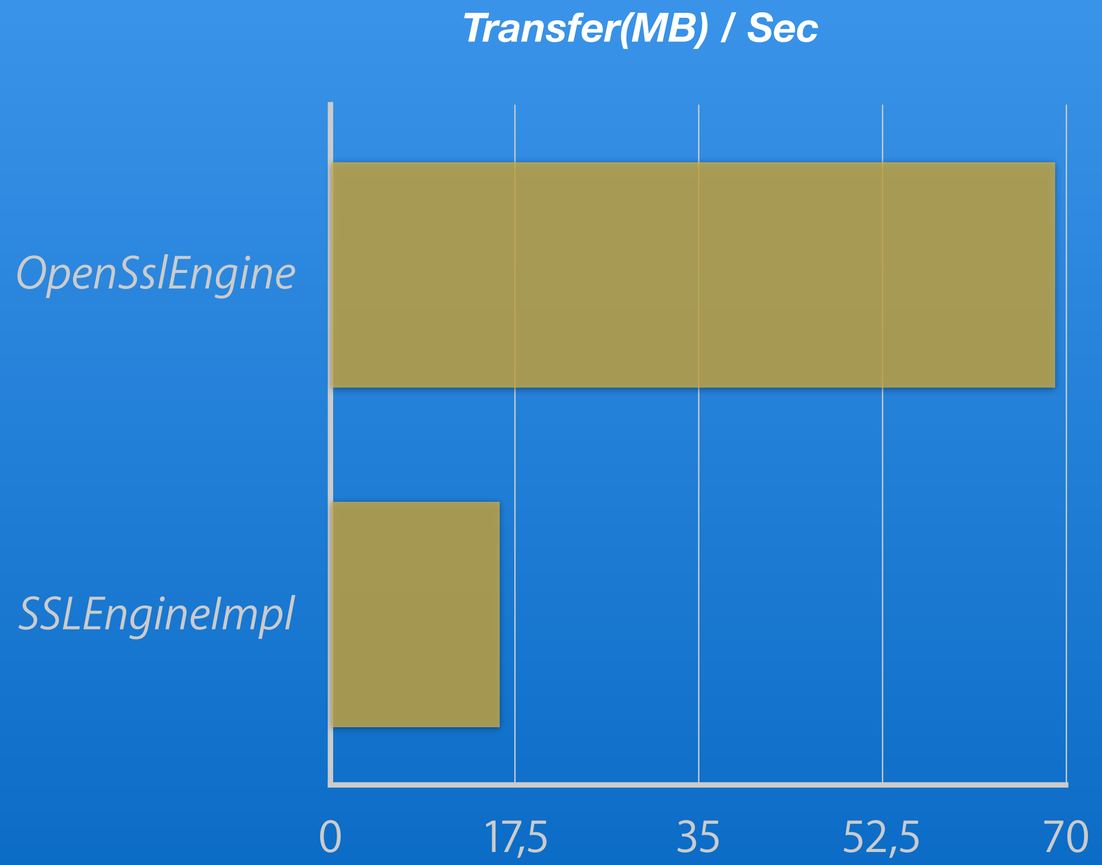
JNI based SSLEngine

… to the rescue



SSLEngine implementations



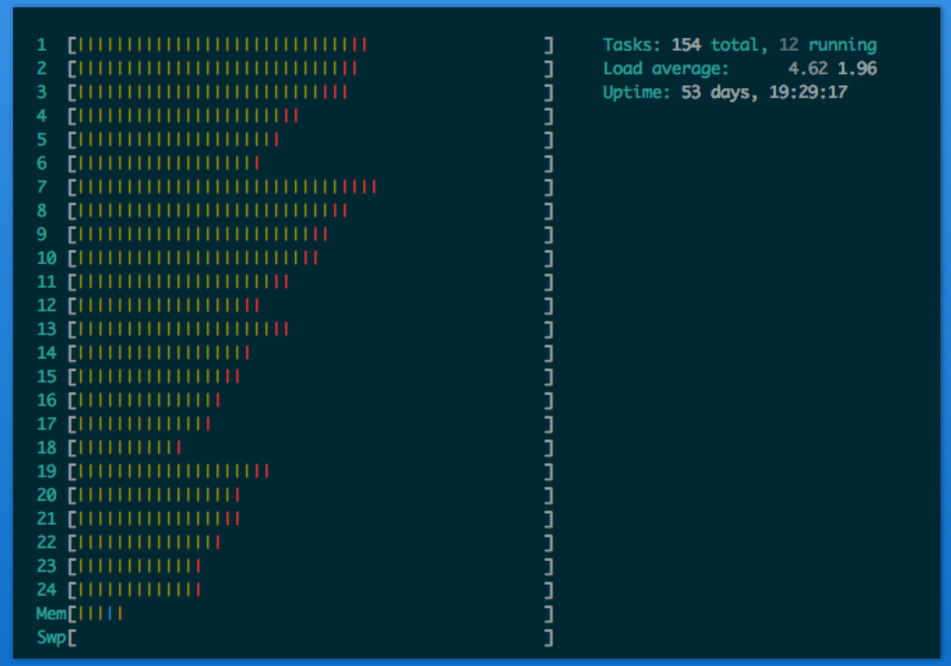


SSLEngine implementations

OpenSslEngine

VS

SSLEngineImpl



OpenSslEngine

```
SslContextBuilder.forServer()
   .sslProvider(
     SslProvider.OpenSsl);
```

- drop in replacement for JDK SSLEngine (SSLEngineImpl)
- gives you up to 6 x performance
- less memory usage
- less GC

Netty and the JVM

A Hate-Love-Relationship

Direct memory management

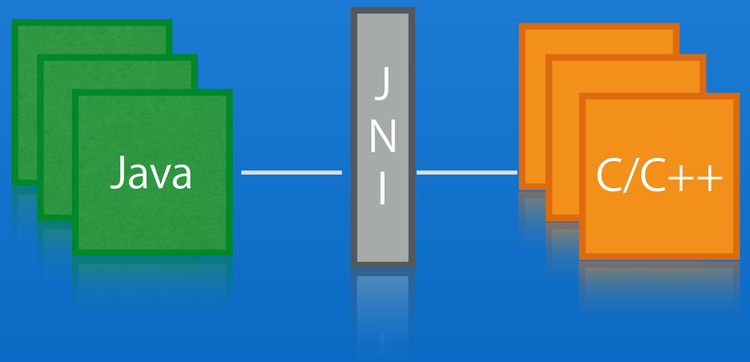
- the whole idea of managing direct memory with via the Garbage-Collector is fundamentally broken
- static *synchronized* in allocation and deallocation methods of direct memory
- there is also *Thread.sleep(100)* and *System.gc()* ?!?

Memory Layout - ENOCONTROL

- no easy way to control over memory layout (all these hacks ….)
- false-sharing is a real issue on own data-structures
- *@Contended* does not help at all in practice

JNI

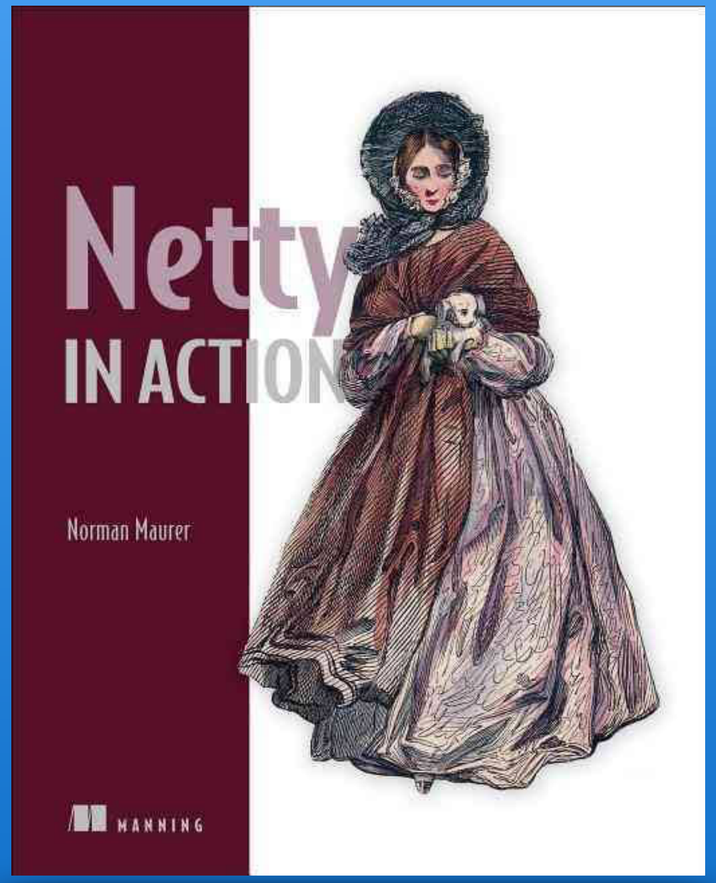
- nasty “hacks” needed to be able to get good performance
- includes things like writing structs directly via *sun.misc.Unsafe* (no joke!)
- calling from JNI into Java methods is SUPER-expensive



NIO / IO and others

- NIO.2 no real improvement over NIO
- too much garbage produced and so GC overhead
- *ByteBuffer* API is not user-friendly (flip all the things!)
- *IOException* / *ConnectException* are too generic and not useful
- creating *String* from *byte[]* / *char[]* not possible without memory copy
- *java.util.concurrent.Future* was (and still is) a disaster

Get my book…



Ka-ching!

Questions?

Thanks!