Netty @ Apple

Massive Scale Deployment / Connectivity

This is not a contribution

Norman Maurer

- Senior Software Engineer @ Apple
- Core Developer of Netty
- Formerly worked @ Red Hat as Netty Project Lead (internal Red Hat)
- Author of Netty in Action (Published by Manning)
- Apache Software Foundation
- Eclipse Foundation

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Massive Scale

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Massive Scale

What does “Massive Scale” mean…

- Instances of Netty based Services in Production: 400,000+
- Data / Day: 10s of PetaBytes
- Requests / Second: 10s of Millions
- Versions: 3.x (migrating to 4.x), 4.x

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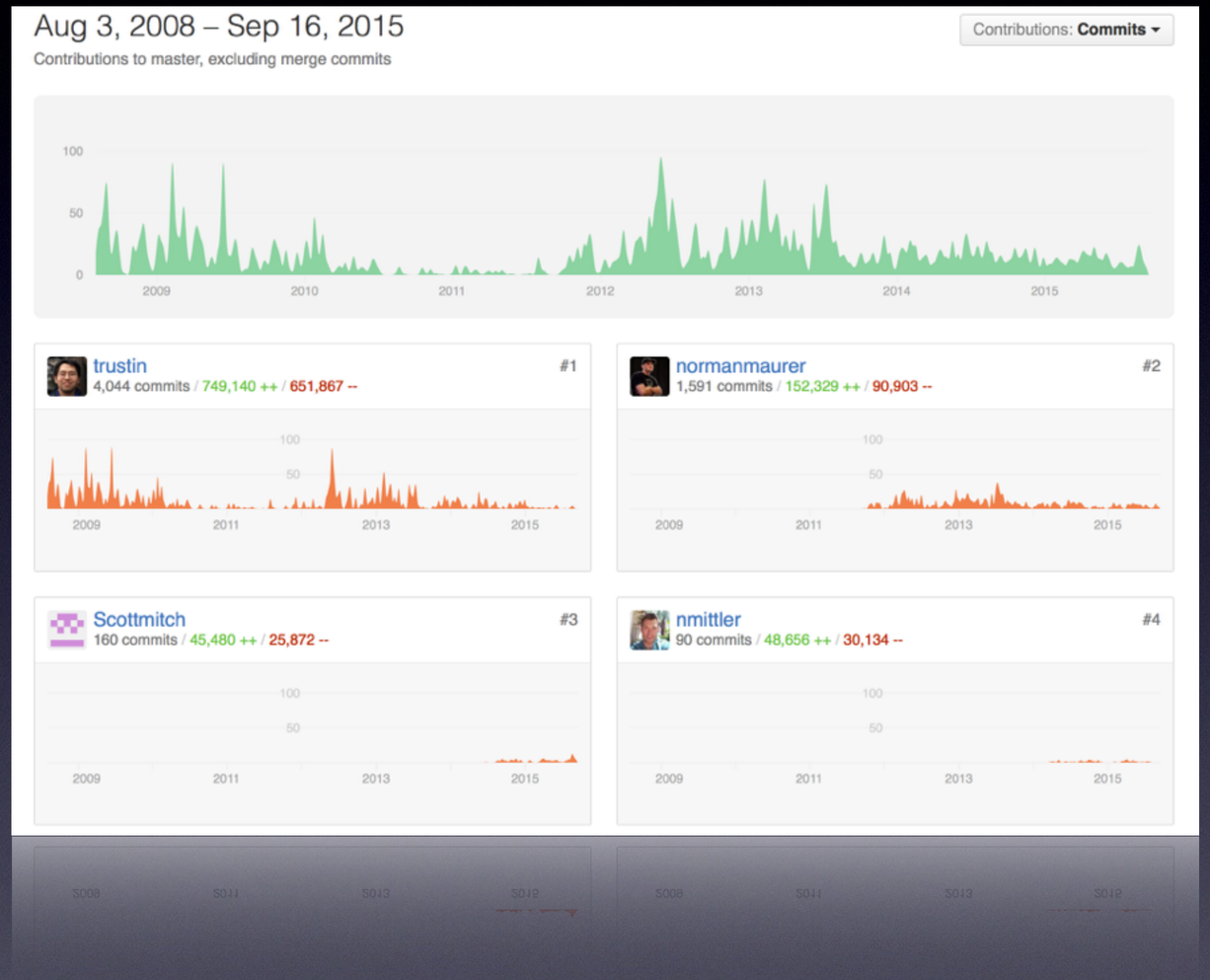
Part of the OSS Community



- Contributing back to the Community
- 250+ commits from Apple Engineers in 1 year

This is not a contribution

Services

Using an Apple Service?

Chances are good Netty is involved somehow.

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Areas of importance

- Native Transport
- TCP / UDP / Domain Sockets
- PooledByteBufAllocator
- OpenSslEngine
- ChannelPool
- Build-in codecs + custom codecs for different protocols

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With Scale comes Pain

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JDK NIO

… some pains

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Some of the pains

- Selector.selectedKeys() produces too much garbage
- NIO implementation uses synchronized everywhere!
- Not optimized for typical deployment environment (support common denominator of all environments)
- Internal copying of heap buffers to direct buffers

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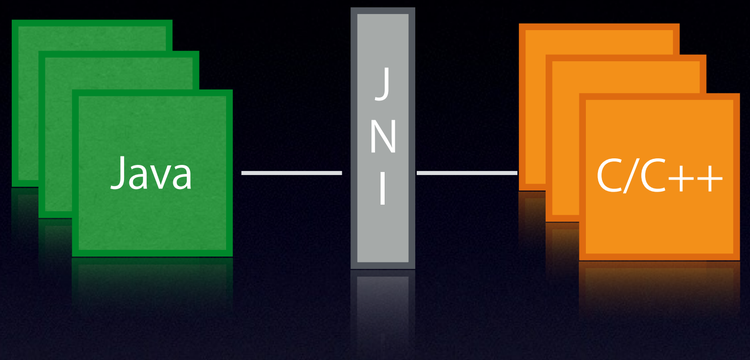
JNI to the rescue



- Optimized transport for Linux only
- Supports Linux specific features
- Directly operate on pointers for buffers
- Synchronization optimized for Netty's Thread-Model

This is not a contribution

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

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Buffers

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JDK ByteBuffer

- Direct buffers are free'ed by GC
  - Not run frequently enough
  - May trigger GC
- Hard to use due not separate indices

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Buffers

- Direct buffers == expensive
- Heap buffers == cheap (but not for free*)
- Fragmentation

*byte[] needs to be zero-out by the JVM!

Buffers - Memory fragmentation

- Waste memory
- May trigger GC due lack of coalesced free memory

Can’t insert int here as we need 4 continuous slots

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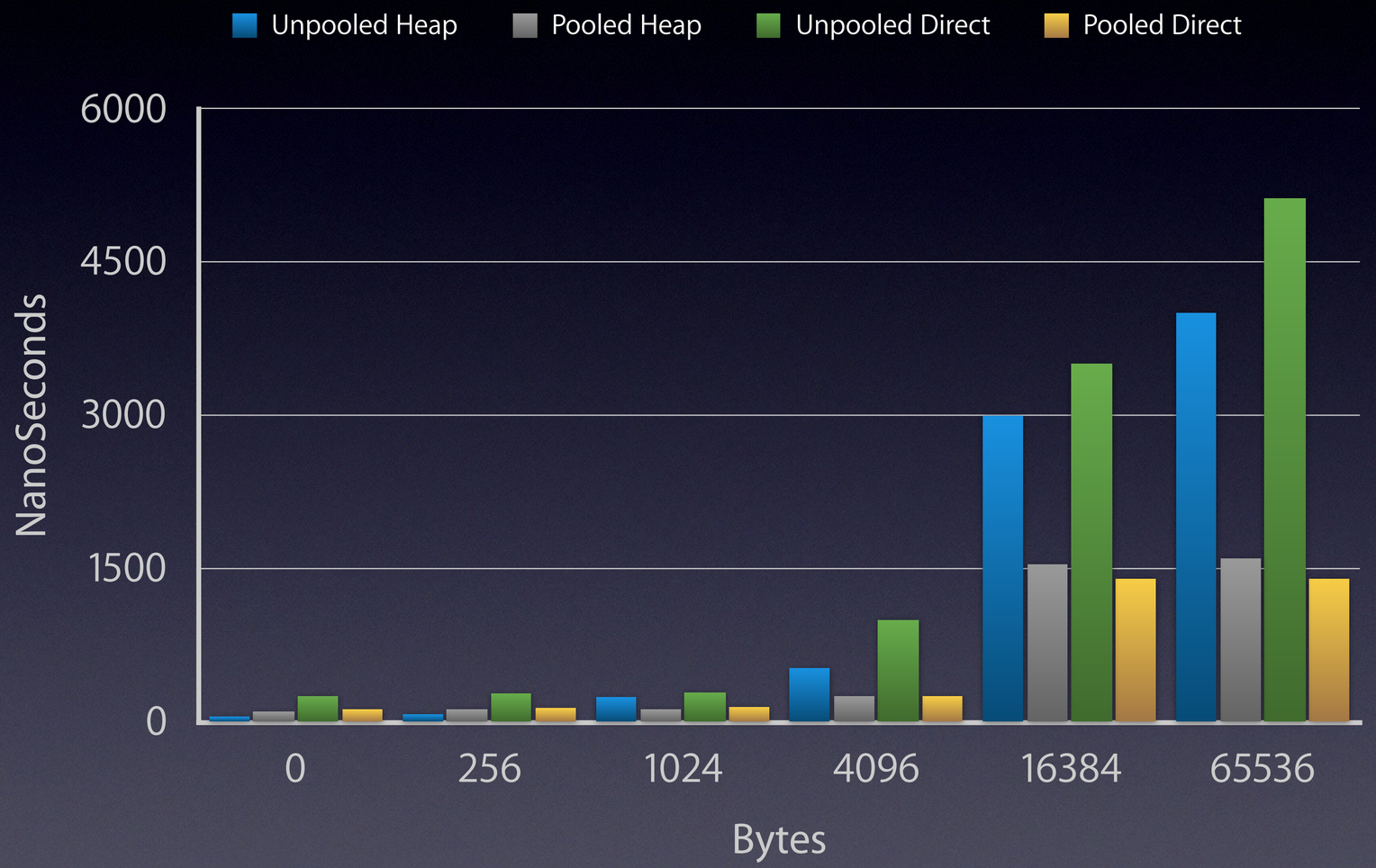
Allocation times



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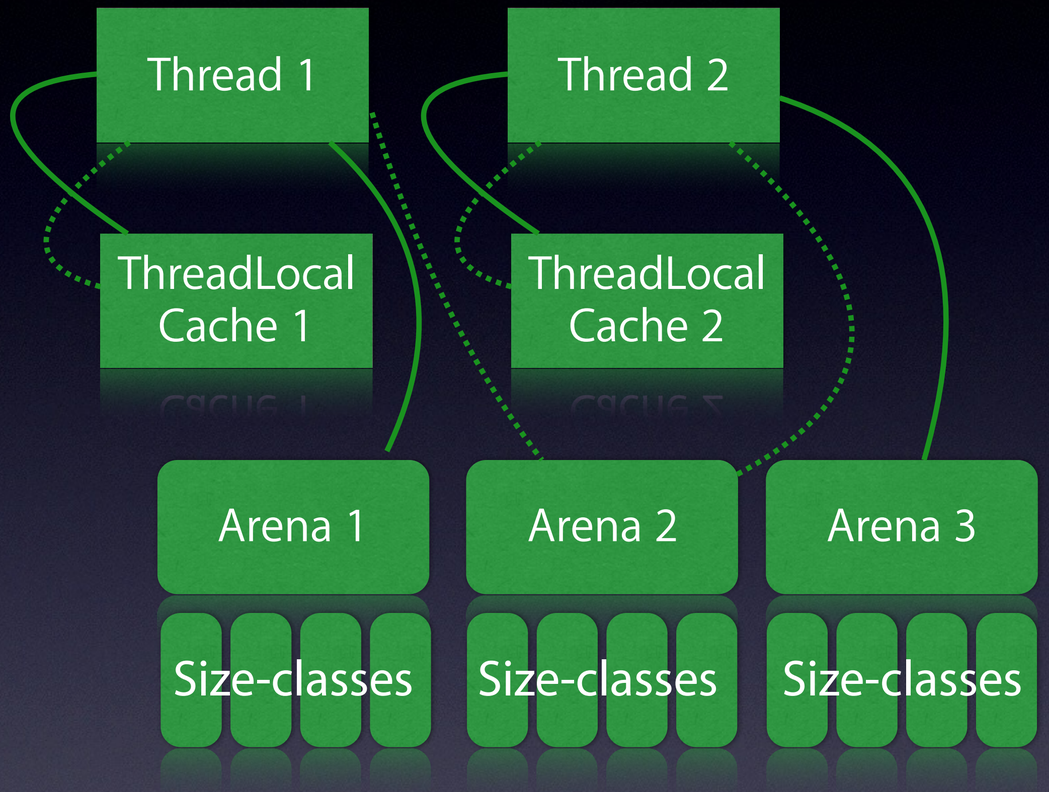
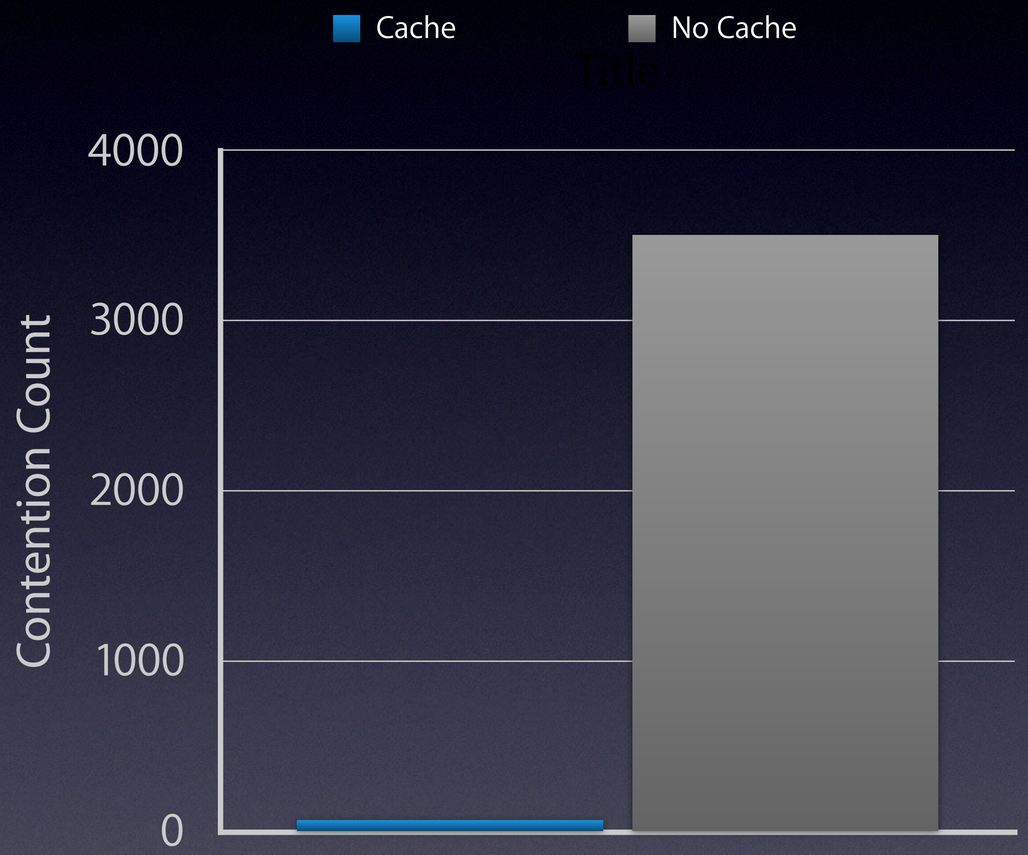
PooledByteBufAllocator



- Based on jemalloc paper (3.x)
- ThreadLocal caches for lock-free allocation in most cases #808
- Synchronize per Arena that holds the different chunks of memory
- Different size classes
- Reduce fragmentation

ThreadLocal caches



- Able to enable / disable ThreadLocal caches
- Fine tuning of Caches can make a big difference
- Best effect if number of allocating Threads are low.
- Using ThreadLocal + MPSC queue #3833

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JDK SSL Performance

…. it’s slow!

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Why handle SSL directly?

- Secure communication between services
- Used for HTTP2 / SPDY negotiation
- Advanced verification of Certificates

Unfortunately JDK's SSLEngine implementation is very slow :(

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HTTPS Benchmark

JDK SSLEngine implementation

Response

HTTP/1.1 200 OK
Content-Length: 15
Content-Type: text/plain; charset=UTF-8
Server: Netty.io
Date: Wed, 17 Apr 2013 12:00:00 GMT

Hello, World!

Result

Running 2m test @ https://xxx:8080/plaintext
16 threads and 256 connections
Thread Stats Avg Stdev Max +/- Stdev
Latency 553.70ms 81.74ms 1.43s 80.22%
Req/Sec 7.41k 595.69 8.90k 63.93%
14026376 requests in 2.00m, 1.89GB read
Socket errors: connect 0, read 0, write 0, timeout 114
Requests/sec: ***116883.21***
Transfer/sec: ***16.16MB***

Benchmark

./wrk -H 'Host: localhost' -H 'Accept: text/html,application/xhtml+xml,application/xml;q=0.9,/*;q=0.8' -H 'Connection: keep-alive' -d 120 -c 256 -t 16 -s scripts/pipeline-many.lua https://xxx:8080/plaintext*

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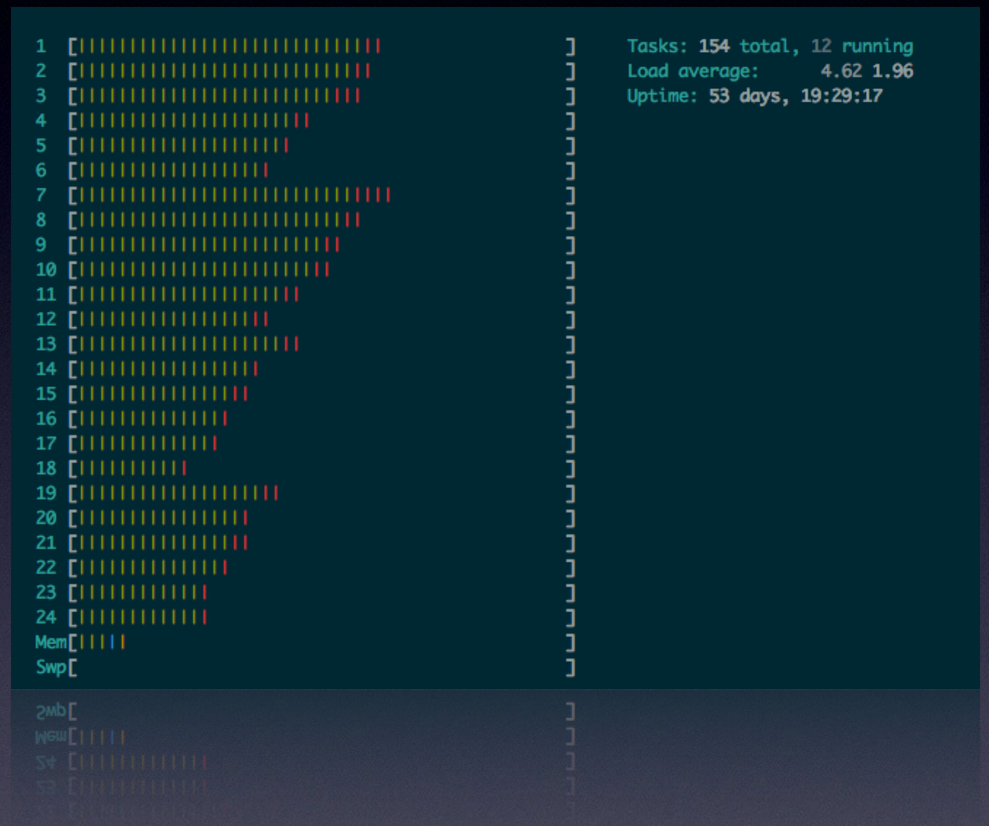
HTTPS Benchmark

JDK SSLEngine implementation



- Unable to fully utilize all cores
- SSLEngine API limiting in some cases
  - SSLEngine.unwrap(…) can only take one ByteBuffer as src

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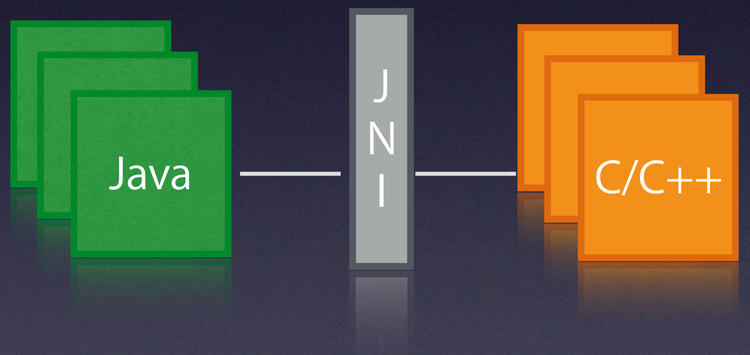
JNI based SSLEngine

… to the rescue



This is not a contribution

JNI based SSLEngine

…one to rule them all

- Supports OpenSSL, LibreSSL and BoringSSL
- Based on Apache Tomcat Native
- Was part of Finagle but contributed to Netty in 2014

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HTTPS Benchmark

OpenSSL SSLEngine implementation

Response

HTTP/1.1 200 OK
Content-Length: 15
Content-Type: text/plain; charset=UTF-8
Server: Netty.io
Date: Wed, 17 Apr 2013 12:00:00 GMT

Hello, World!

Result

Running 2m test @ https://xxx:8080/plaintext
16 threads and 256 connections
Thread Stats Avg Stdev Max +/- Stdev
Latency 131.16ms 28.24ms 857.07ms 96.89%
Req/Sec 31.74k 3.14k 35.75k 84.41%
60127756 requests in 2.00m, 8.12GB read
Socket errors: connect 0, read 0, write 0, timeout 52
Requests/sec: ***501120.56***
Transfer/sec: ***69.30MB***

Benchmark

./wrk -H 'Host: localhost' -H 'Accept: text/html,application/xhtml+xml,application/xml;q=0.9,/*;q=0.8' -H 'Connection: keep-alive' -d 120 -c 256 -t 16 -s scripts/pipeline-many.lua https://xxx:8080/plaintext*

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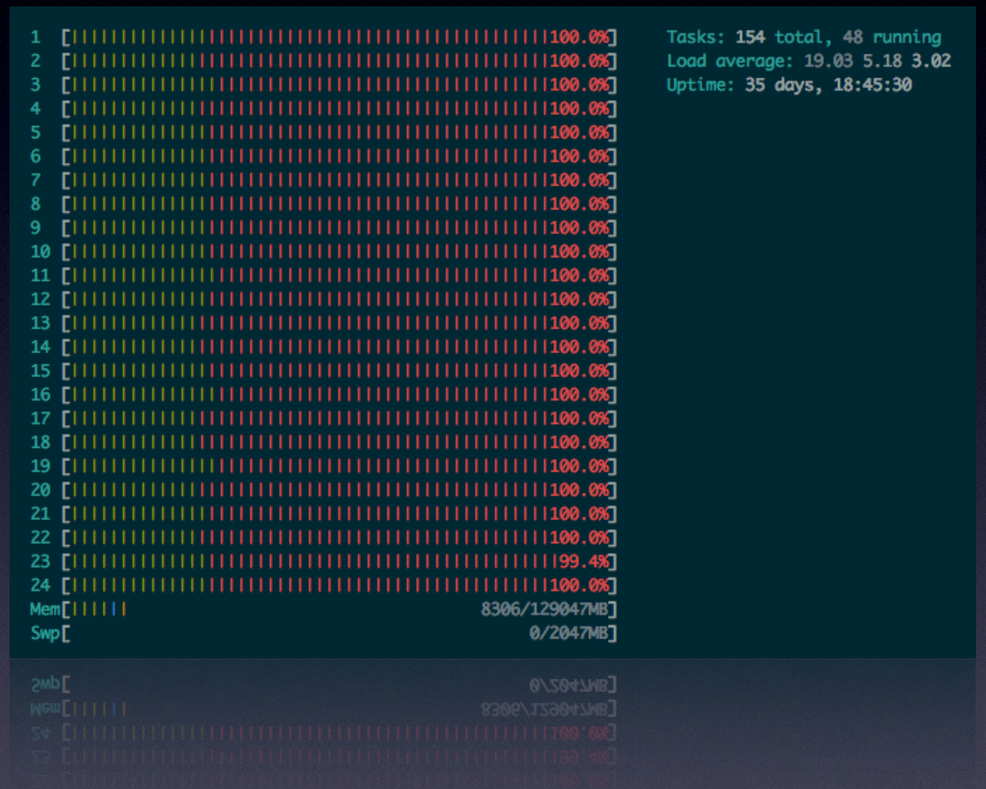
HTTPS Benchmark

OpenSSL SSLEngine implementation



- All cores utilized!
- Makes use of native code provided by OpenSSL
- Low object creation
- Drop in replacement*

*supported on Linux, OSX and Windows

This is not a contribution

Optimizations made

- Added client support: #7, #11, #3270, #3277, #3279
- Added support for Auth: #10, #3276
- GC-Pressure caused by heavy object creation: #8, #3280, #3648
- Too many JNI calls: #3289
- Proper SSLSession implementation: #9, #16, #17, #20, #3283, #3286, #3288
- ALPN support #3481
- Only do priming read if there is no space in dsts buffers #3958

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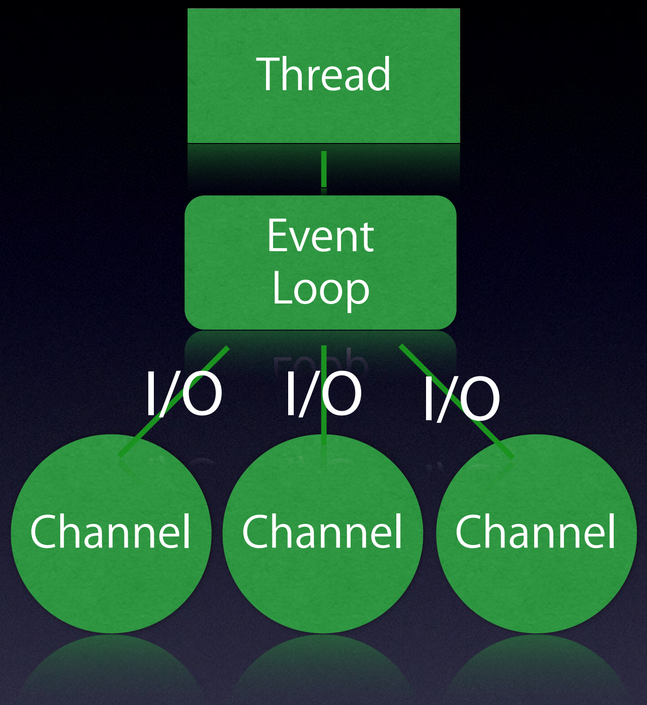
Thread Model



- Easier to reason about
- Less worry about concurrency
- Easier to maintain
- Clear execution order

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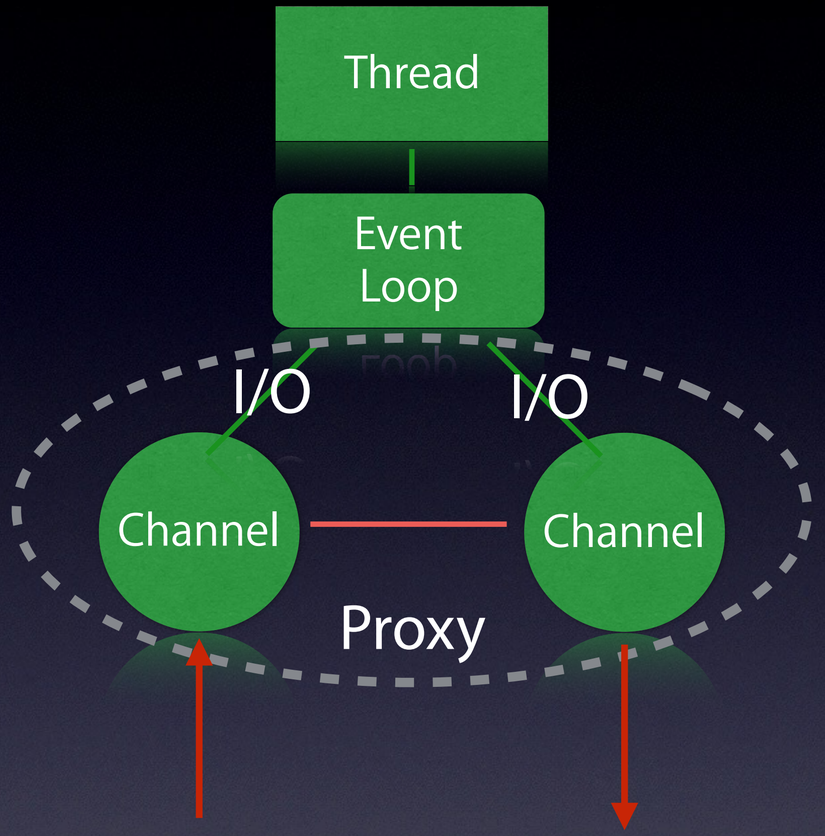
Thread Model




```
public class ProxyHandler extends ChannelInboundHandlerAdapter {
  @Override
  public void channelActive(ChannelHandlerContext ctx) {
    final Channel inboundChannel = ctx.channel();
    Bootstrap b = new Bootstrap();
    b.group(inboundChannel.eventLoop());
    ctx.channel().config().setAutoRead(false);
    ChannelFuture f = b.connect(remoteHost, remotePort);
    f.addListener(f -> {
       if (f.isSuccess()) {
           ctx.channel().config().setAutoRead(true);
       } else { ...}
    });
  }
}
```

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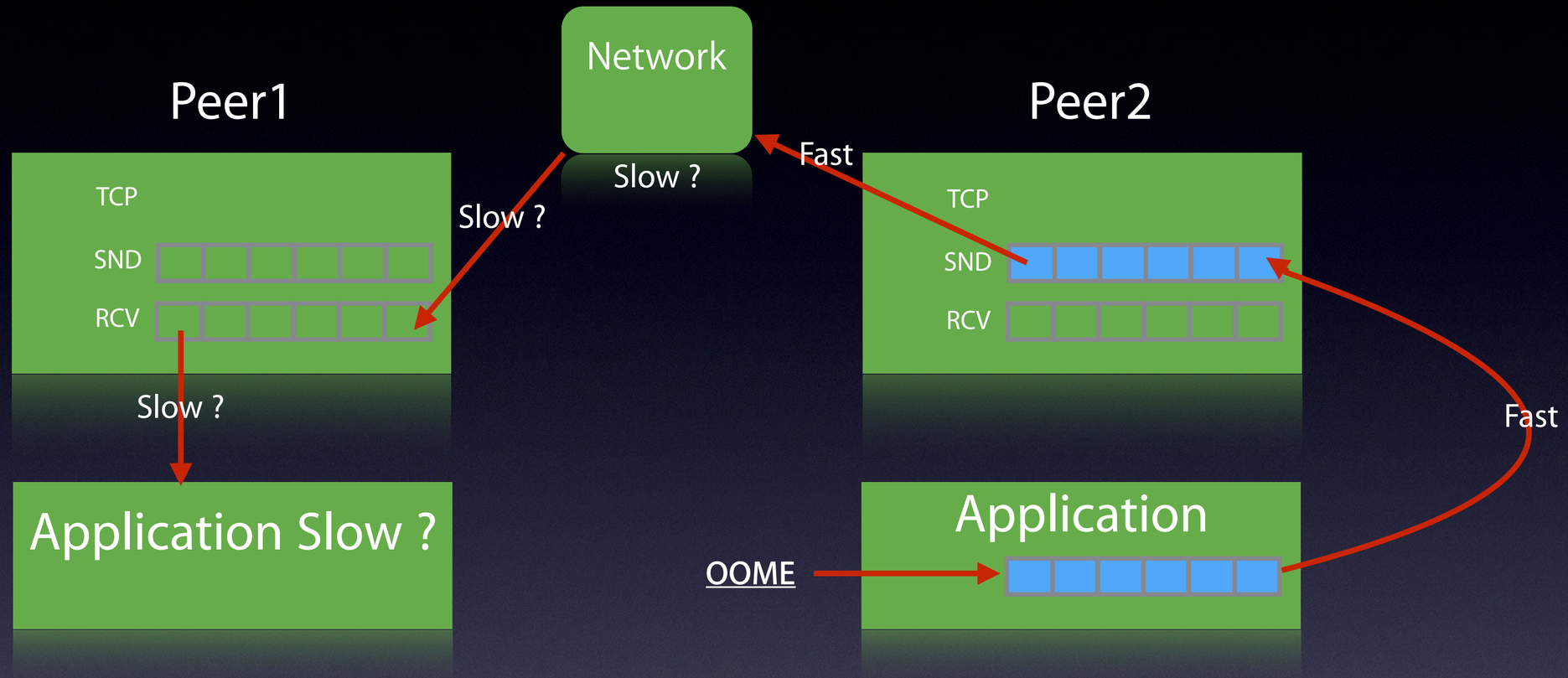
Backpressure



- Slow peers due slow connection
- Risk of writing too fast
- Backoff writing and reading

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Memory Usage

- Handling a lot of concurrent connections
- Need to safe memory to reduce heap sizes
  - Use Atomic*FieldUpdater
  - Lazy init fields

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Connection Pooling

- Having an extensible connection pool is important #3607
- flexible / extensible implementation

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Thanks

We are hiring!
http://www.apple.com/jobs/us/

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