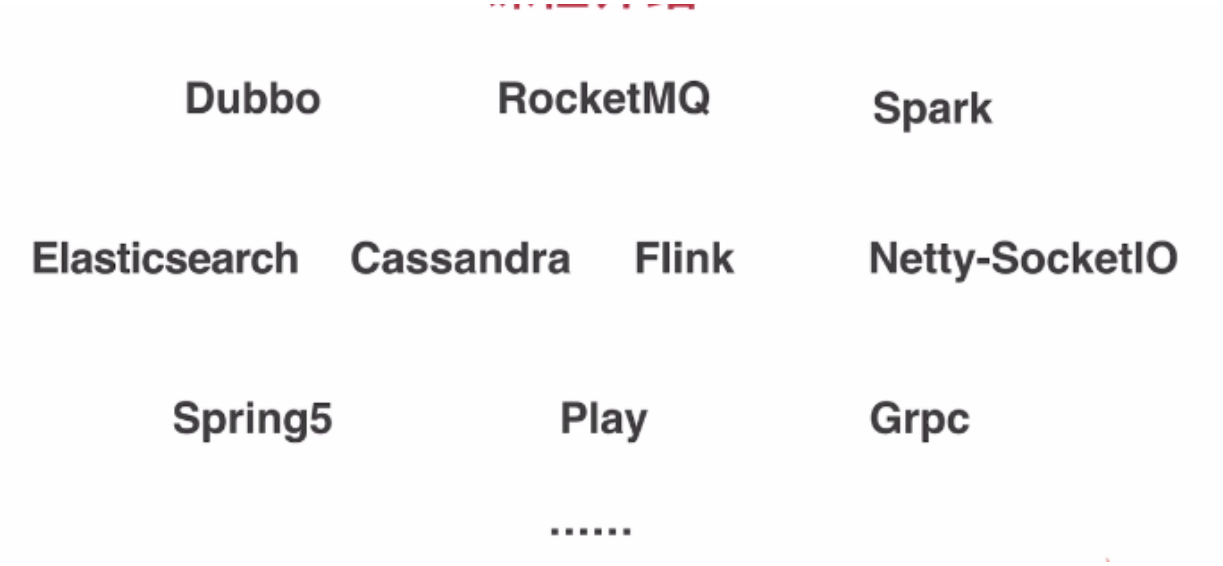
Netty 深入剖析

一 netty简介

1.1 业界使用netty的开源框架

- dubbo
- RocketMQ
- Spark
- ElasticSearch
- Cassandra 开源分布式nosql数据库
- Flink 分布式高性能高可用的流处理框架
- Netty-SocketIo socketIo协议的java服务端实现
- Spring5 使用netty作为http协议框架
- Grpc 谷歌开源的高性能Rpc框架



1.2. Netty是什么？ 为什么使用netty之后，几乎不用担心性能问题

- 异步事件驱动框架，用于快速开发高性能服务端和客户端
- 封装了JDK底层BIO和NIO模型，提供高度可用的API（提供了非常多的扩展点，使API更加灵活丰富，channelHandler热插拔机制，解放了业务逻辑之外的细节问题，使业务逻辑的热添加和删除变得容易）
- 自带编解码器解决了拆包粘包问题，用户只用关心业务逻辑
- 精心设计的reactor线程模型支持高并发海量连接（为什么netty只使用了少量的线程，就能管理成千上万甚至几十万的连接）
- 自带各种协议栈让你处理任何一种通用协议都几乎不用亲自动手

1.3. 为什么学netty

- 各大开源框架选择netty作为底层通信框架
- 更好的使用，少走弯路
- 单机连接数上不去？性能遇到瓶颈？如何调优
- 详解reactor线程模型，实践中举一反三

- 庞大的项目是如何组织的，设计模式，体验优秀的设计
- 阅读源码 -- 可以作为第一个深入研究的开源框架

1.4. 目标

- 掌握netty底层核心原理，解决各类问题，深度调优
- 给netty官方提issue
- 实现一个简易版的netty
- 开启阅读源码之旅
- 加速掌握基于netty的各类中间件

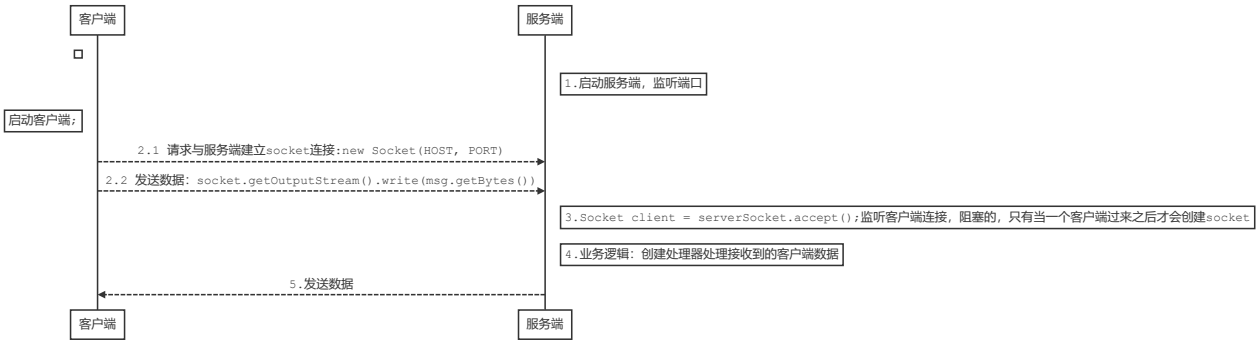
1.5. 技术储备

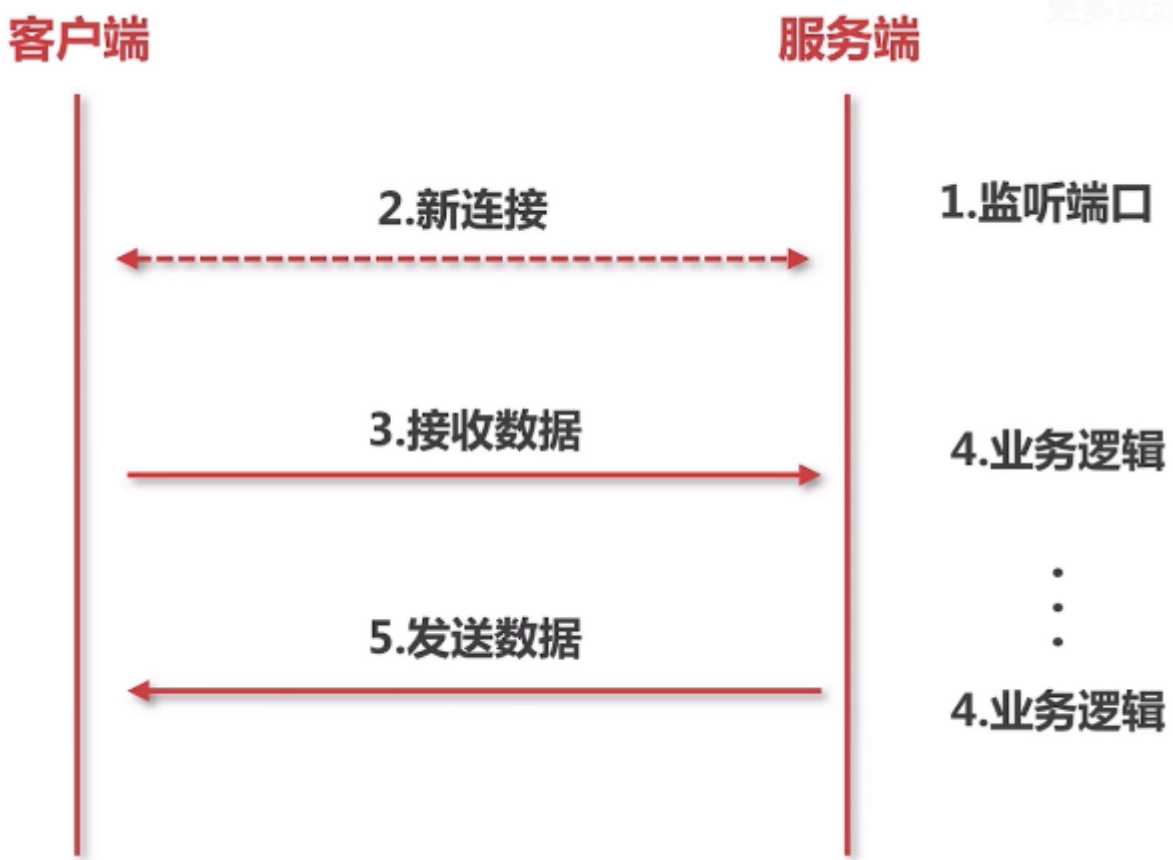
- java基础，多线程
- TCP原理， NIO

二 netty基本组件

包括：NioEventLoop（发动机：起了两种类型的线程），Channel（对连接的封装，数据读写），ByteBuf（数据流），Pipeline（逻辑处理链），ChannelHandler（逻辑）

2.1 不使用netty情况下，模拟传统的客户端与服务端通信



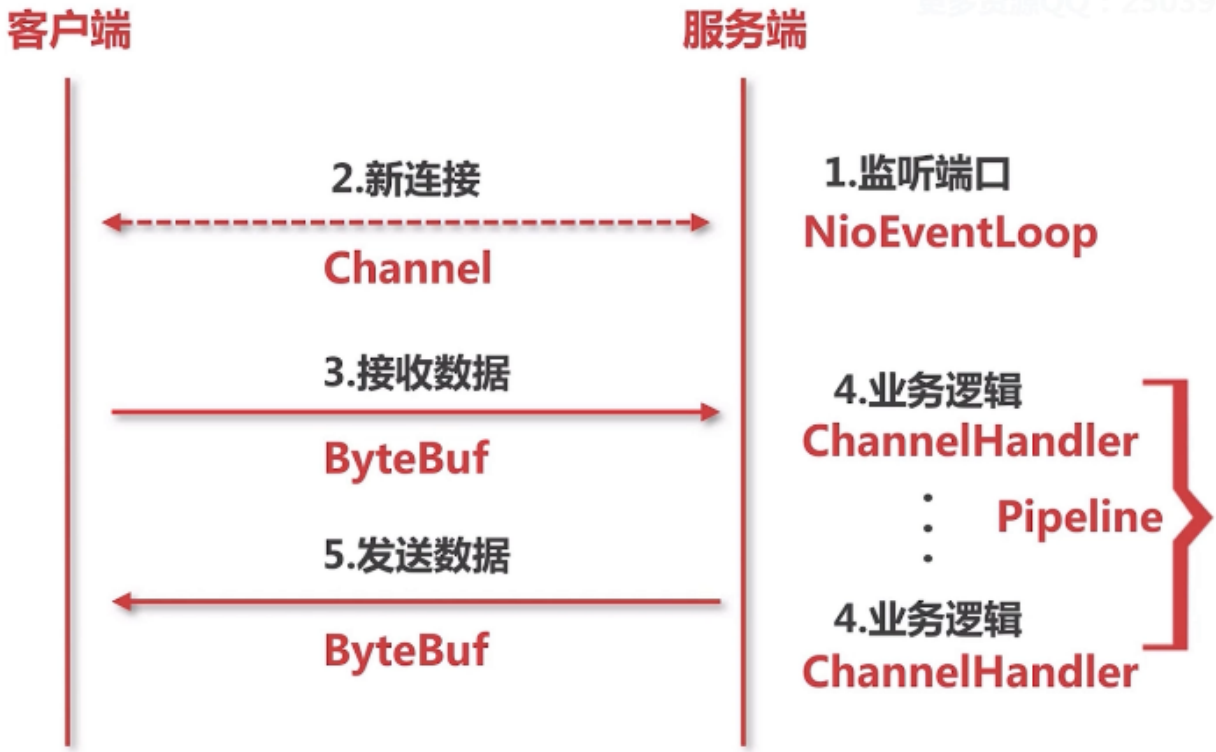


2.1.1 监听端口实际包含两层含义：对应两个while循环

a）server不断的在某个端口上监听新用户的连接

b）新用户的连接建立完成后，在对应的端口上不断的监听新连接的数据

netty实现：



2.2 netty - NioEventLoop

对应socket编程的线程

NioEventLoop： nio事件循环

2.2.1 新连接的接入

2.2.2 当前存在的连接上数据流的读写

2.3 netty - channel

```
channel 定义:
* A nexus to a network socket or a component which is capable of I/O
* operations such as read, write, connect, and bind.
```

对应socket编程的socket

端口上监听到的新用户的连接

io.netty.channel.nio.AbstractNioMessageChannel#doReadMessages

```
SocketChannel ch = javaChannel().accept();
```

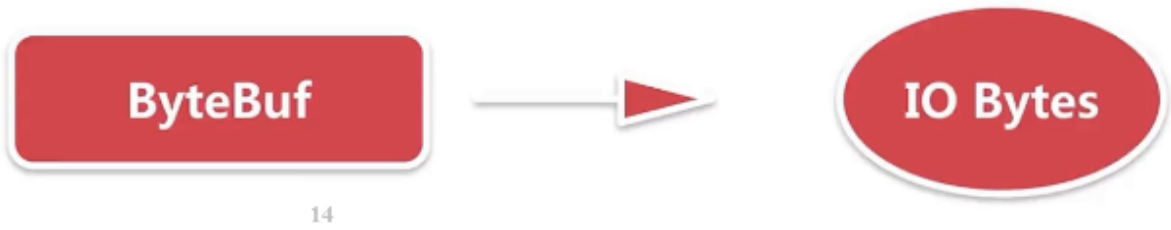
java IO编程模型 -- 当作socket处理

NIO编程模型 -- socketChannel

netty -- 封装成自定义的channel

基于channel，一系列的读写都可以在这个连接上操作，其实就是对socket的抽象

2.4 netty - ByteBuf



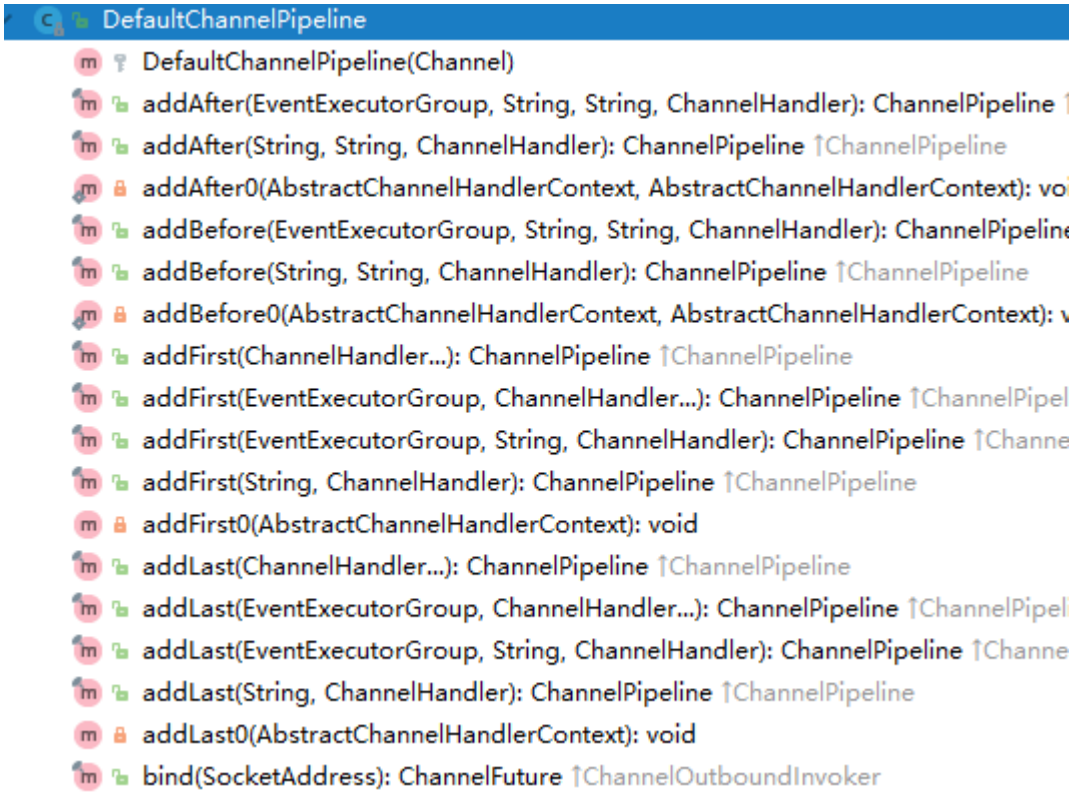
服务端接受用户的数据流的载体都是基于ByteBuf，封装了很多api可以与底层的连接的数据流通信

2.5 netty - channelHandler

服务端处理业务逻辑的处理器

io.netty.channel.DefaultChannelPipeline#addFirst(io.netty.channel.ChannelHandler...)

通过ChannelPipeline可以动态的添加channelHandler




```
@Override
public final ChannelPipeline addFirst(ChannelHandler... handlers) {
    return addFirst(null, handlers);
}
```

实际生产环境下，客户端与服务端的通信的时候都很复杂，

一般都需要定义二进制的协议，对二进制协议的数据进行数据包的拆分，对不同类型的协议数据包转换成不同的java对象并作不同的处理。

netty把每一个处理过程都当作ChannelHandler。

将不同的处理过程交给不同的channelHandler处理。

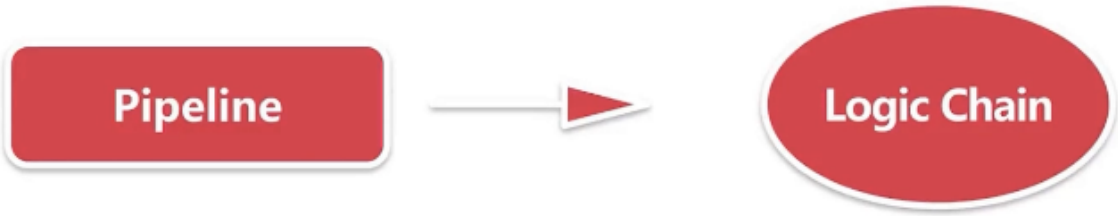
用户可以自定义channelHandler。

例如：数据包分包器

2.6 netty - Pipeline - 逻辑链

netty什么时候将Pipeline加入到每一个客户端连接的处理过程的。

```
protected AbstractChannel(Channel parent, ChannelId id) {
    this.parent = parent;
    this.id = id;
    unsafe = newUnsafe();
    pipeline = newChannelPipeline();
}
```



三. netty服务端启动

```
public final class Server {
    public static void main(String[] args) {
        // bossGroup 对应 socket编程中 server端 的 线程
        EventLoopGroup bossGroup = new NioEventLoopGroup(1);
        // workGroup 对应 socket编程中 client端 的 线程
        EventLoopGroup workGroup = new NioEventLoopGroup();

        ServerBootstrap bootstrap = new ServerBootstrap();

        bootstrap.group(bossGroup, workGroup)
                .channel(NioServerSocketChannel.class)
                .childOption(ChannelOption.TCP_NODELAY, true)
                .childAttr(AttributeKey.newInstance("childAttr"), "childAttrValue")
                .handler(new ServerHandler())
                .childHandler(new ChannelInitializer<SocketChannel>() {

                    @Override
                    protected void initChannel(SocketChannel ch) throws Exception {
                        ch.pipeline().addLast();
                    }
                });
        try {
            //服务端创建的入口 bind()
            ChannelFuture channelFuture = bootstrap.bind(8888).sync();
            channelFuture.channel().closeFuture().sync();
        } catch (InterruptedException e) {
            e.printStackTrace();
        }
    }
}
```

3.1 思考：服务端的socket在哪里初始化？在哪里accept连接？

3.2 netty服务端启动的四个过程

3.2.1 创建服务端channel

```
ChannelFuture channelFuture = bootstrap.bind(8888).sync();
```

```
 private ChannelFuture doBind(final SocketAddress localAddress) {
     final ChannelFuture regFuture = initAndRegister();
     final Channel channel = regFuture.channel();
     ....
 }
```

```
final ChannelFuture initAndRegister() {
    Channel channel = null;
    try {
        channel = channelFactory.newChannel();//创建服务端channel
        init(channel);//初始化服务端channel
    } catch (Throwable t) {
    .....
}
```

```
@Override
public T newChannel() {
    try {
        // 这里的clazz指什么?  --> NioServerSocketChannel.class
        return clazz.newInstance();//反射
    } catch (Throwable t) {
        throw new ChannelException("Unable to create Channel from class " + clazz, t);
    }
}
```

NioServerSocketChannel**如何构造的


```
io.netty.channel.socket.nio.NioServerSocketChannel#NioServerSocketChannel()
public NioServerSocketChannel() {
    this(newSocket(DEFAULT_SELECTOR_PROVIDER));
}
```

```
io.netty.channel.socket.nio.NioServerSocketChannel#NioServerSocketChannel(java.nio.channels.
ServerSocketChannel)

public NioServerSocketChannel(ServerSocketChannel channel) {
    super(null, channel, SelectionKey.OP_ACCEPT);
    config = new NioServerSocketChannelConfig(this, javaChannel().socket());
}
```

```
io.netty.channel.nio.AbstractNioChannel#AbstractNioChannel
protected AbstractNioChannel(Channel parent, SelectableChannel ch, int readInterestOp) {
    super(parent);
    this.ch = ch;
    this.readInterestOp = readInterestOp;
    try {
        ch.configureBlocking(false);
    } catch (IOException e) {
      ...
    }
}
```

```
io.netty.channel.AbstractChannel#AbstractChannel(io.netty.channel.Channel)
protected AbstractChannel(Channel parent) {
    this.parent = parent;
    id = newId();
    unsafe = newUnsafe();
    pipeline = newChannelPipeline();
}
```

3.2.2 初始化服务端channel

- io.netty.bootstrap.AbstractBootstrap#init() 初始化入口
    - set ChannelOptions， ChannelAttrs
    - set ChildOptions，ChildAttrs
    - config handler [配置服务端Pipeline]
    - add ServerBootStrapAcceptor[添加连接接入器]

--》保存用户自定义的属性

--》ServerBootstrapAcceptor 创建新连接接入器（一个特殊的channelHandler）

--》将用户自定义的属性传到新连接接入器中，当accept到一个新连接，通过这几个属性对新的连接进行配置，就可以把一个新的连接绑定到一个新的线程上去。

```
@Override
void init(Channel channel) throws Exception {
    final Map<ChannelOption<?>, Object> options = options0();
    synchronized (options) {
        channel.config().setOptions(options);
    }
```

```
    final Map<AttributeKey<?>, Object> attrs = attrs0();
    synchronized (attrs) {
        for (Entry<AttributeKey<?>, Object> e: attrs.entrySet()) {
            @SuppressWarnings("unchecked")
            AttributeKey<Object> key = (AttributeKey<Object>) e.getKey();
            channel.attr(key).set(e.getValue());
        }
    }

    ChannelPipeline p = channel.pipeline();

    final EventLoopGroup currentChildGroup = childGroup;
    final ChannelHandler currentChildHandler = childHandler;
    final Entry<ChannelOption<?>, Object>[] currentChildOptions;
    final Entry<AttributeKey<?>, Object>[] currentChildAttrs;
    synchronized (childOptions) {
        currentChildOptions =
childOptions.entrySet().toArray(newOptionArray(childOptions.size()));
    }
    synchronized (childAttrs) {
        currentChildAttrs = childAttrs.entrySet().toArray(newAttrArray(childAttrs.size()));
    }

    p.addLast(new ChannelInitializer<Channel>() {
        @Override
        public void initChannel(Channel ch) throws Exception {
            final ChannelPipeline pipeline = ch.pipeline();
            ChannelHandler handler = config.handler();
            if (handler != null) {
                pipeline.addLast(handler);
            }
            ch.eventLoop().execute(new Runnable() {
                @Override
                public void run() {
                    pipeline.addLast(new ServerBootstrapAcceptor(
                            currentChildGroup, currentChildHandler, currentChildOptions,
currentChildAttrs));
                }
            });
        }
    });
}
```

3.2.3 将channel注册到事件轮询器selector

- io.netty.channel.AbstractChannel.AbstractUnsafe#register（channel）[入口]
- this.eventLoop = eventLoop [绑定线程]
- io.netty.channel.AbstractChannel.AbstractUnsafe#register0 [实际注册]
    - io.netty.channel.AbstractChannel#doRegister [调用底层JDK底层注册]
    - io.netty.channel.DefaultChannelPipeline#invokeHandlerAddedIfNeeded [添加channelHandler的时候触发用户回调]

- io.netty.channel.DefaultChannelPipeline#fireChannelActive [传播channel注册成功事件到用户代码方法]

```
#ChannelFuture regFuture = config().group().register(channel);

@Override
        public final void register(EventLoop eventLoop, final ChannelPromise promise) {
            if (eventLoop == null) {
                throw new NullPointerException("eventLoop");
            }
            if (isRegistered()) {
                promise.setFailure(new IllegalStateException("registered to an event loop
already"));
                return;
            }
            if (!isCompatible(eventLoop)) {
                promise.setFailure(
                        new IllegalStateException("incompatible event loop type: " +
eventLoop.getClass().getName()));
                return;
            }
            // 处理所有I/O事件
            AbstractChannel.this.eventLoop = eventLoop;
            if (eventLoop.inEventLoop()) {
                register0(promise);
            } else {
                try {
                    eventLoop.execute(new Runnable() {
                        @Override
                        public void run() {
                            register0(promise);
                        }
                    });
                } catch (Throwable t) {
                    logger.warn(
                            "Force-closing a channel whose registration task was not
accepted by an event loop: {}",
                            AbstractChannel.this, t);
                    closeForcibly();
                    closeFuture.setClosed();
                    safeSetFailure(promise, t);
                }
            }
        }
```

```
private void register0(ChannelPromise promise) {
    try {
        // check if the channel is still open as it could be closed in the mean time when
the register
        // call was outside of the eventLoop
        if (!promise.setUncancellable() || !ensureOpen(promise)) {
            return;
```

```
        }
        boolean firstRegistration = neverRegistered;
        doRegister();
        neverRegistered = false;
        registered = true;

        // Ensure we call handlerAdded(...) before we actually notify the promise. This is
needed as the
        // user may already fire events through the pipeline in the ChannelFutureListener.
        pipeline.invokeHandlerAddedIfNeeded();

        safeSetSuccess(promise);
        pipeline.fireChannelRegistered();
        // Only fire a channelActive if the channel has never been registered. This prevents
firing
        // multiple channel actives if the channel is deregistered and re-registered.
        if (isActive()) {
            if (firstRegistration) {
                pipeline.fireChannelActive();
            } else if (config().isAutoRead()) {
                // This channel was registered before and autoRead() is set. This means we
need to begin read
                // again so that we process inbound data.
                //
                // See https://github.com/netty/netty/issues/4805
                beginRead();
            }
        }
    } catch (Throwable t) {
        // Close the channel directly to avoid FD leak.
        closeForcibly();
        closeFuture.setClosed();
        safeSetFailure(promise, t);
    }
}
```

io.netty.channel.nio.AbstractNioChannel#doRegister

```
@Override
protected void doRegister() throws Exception {
    boolean selected = false;
    for (;;) {
        try {
            //调用jdk底层的注册方法 this代表 NioServerSocketChannel.class
            //将NioServerSocketChannel作为一个attachment传到jdk底层的channel
            selectionKey = javaChannel().register(eventLoop().selector, 0, this);
            return;
        } catch (CancelledKeyException e) {
            if (!selected) {
                eventLoop().selectNow();
                selected = true;
            } else {
                // We forced a select operation on the selector before but the SelectionKey
```

```
is still cached
                // for whatever reason. JDK bug ?
                throw e;
            }
        }
    }
}
```

java.nio.channels.SelectableChannel#register(java.nio.channels.Selector, int, java.lang.Object)

```
* @param  sel
*         The selector with which this channel is to be registered
* @param  ops
*         The interest set for the resulting key
* @param  att
*         The attachment for the resulting key; may be <tt>null</tt>
 public abstract SelectionKey register(Selector sel, int ops, Object att)
        throws ClosedChannelException;
```

3.2.4 端口绑定

- io.netty.channel.AbstractChannel.AbstractUnsafe#bind [入口]
- io.netty.channel.AbstractChannel#doBind

```
@Override
public final void bind(final SocketAddress localAddress, final ChannelPromise promise) {
    assertEventLoop();

    if (!promise.setUncancellable() || !ensureOpen(promise)) {
        return;
    }
    if (Boolean.TRUE.equals(config().getOption(ChannelOption.SO_BROADCAST)) &&
        localAddress instanceof InetSocketAddress &&
        !((InetSocketAddress) localAddress).getAddress().isAnyLocalAddress() &&
        !PlatformDependent.isWindows() && !PlatformDependent.isRoot()) {
        logger.warn(
                "A non-root user can't receive a broadcast packet if the socket " +
                "is not bound to a wildcard address; binding to a non-wildcard " +
                "address (" + localAddress + ") anyway as requested.");
    }
    //端口绑定之前是false, doBind之后变为true
    boolean wasActive = isActive();
    try {

        doBind(localAddress);

    } catch (Throwable t) {
        safeSetFailure(promise, t);
        closeIfClosed();
        return;
```

```
    }

    //端口绑定之前不是active，绑定之后编程active
    if (!wasActive && isActive()) {
        invokeLater(new Runnable() {
            @Override
            public void run() {
                //传播事件
                pipeline.fireChannelActive();
            }
        });
    }

    safeSetSuccess(promise);
}
```

io.netty.channel.socket.nio.NioServerSocketChannel#doBind

```
@Override
protected void doBind(SocketAddress localAddress) throws Exception {
    if (PlatformDependent.javaVersion() >= 7) {
        //调用java底层api
        javaChannel().bind(localAddress, config.getBacklog());
    } else {
        javaChannel().socket().bind(localAddress, config.getBacklog());
    }
}
```

io.netty.channel.DefaultChannelPipeline.HeadContext#channelActive

```
@Override
public void channelActive(ChannelHandlerContext ctx) throws Exception {
    ctx.fireChannelActive();

    readIfIsAutoRead();
}
```

io.netty.channel.DefaultChannelPipeline.HeadContext#readIfIsAutoRead

```
private void readIfIsAutoRead() {
    if (channel.config().isAutoRead()) {
        channel.read();
    }
}
```

io.netty.channel.AbstractChannel#read

```
@Override
public Channel read() {
    pipeline.read();
    return this;
}
```

io.netty.channel.AbstractChannelHandlerContext#read

```
@Override
public ChannelHandlerContext read() {
    final AbstractChannelHandlerContext next = findContextOutbound();
    EventExecutor executor = next.executor();
    if (executor.inEventLoop()) {
        next.invokeRead();
    } else {
        Runnable task = next.invokeReadTask;
        if (task == null) {
            next.invokeReadTask = task = new Runnable() {
                @Override
                public void run() {
                    next.invokeRead();
                }
            };
        }
        executor.execute(task);
    }

    return this;
}
```

io.netty.channel.DefaultChannelPipeline.HeadContext#read

```
@Override
public void read(ChannelHandlerContext ctx) {
    unsafe.beginRead();
}
```

io.netty.channel.AbstractChannel.AbstractUnsafe#beginRead

```
@Override
public final void beginRead() {
    assertEventLoop();

    if (!isActive()) {
        return;
    }
    try {
        doBeginRead();
    } catch (final Exception e) {
```

```
        invokeLater(new Runnable() {
            @Override
            public void run() {
                pipeline.fireExceptionCaught(e);
            }
        });
        close(voidPromise());
    }
}
```

io.netty.channel.nio.AbstractNioChannel#doBeginRead

```
@Override
protected void doBeginRead() throws Exception {
    // Channel.read() or ChannelHandlerContext.read() was called
    //channel注册到selector上后返回的key，key对应channel
    final SelectionKey selectionKey = this.selectionKey;
    if (!selectionKey.isValid()) {
        return;
    }

    readPending = true;

    //Retrieves this key's interest set
    final int interestOps = selectionKey.interestOps();
    //与运算
    if ((interestOps & readInterestOp) == 0) {
        //将2者进行或运算以后重新注册到selectionKey上  即在之前事件的基础上再增加一个事件
        //readInterestOp 其实是NioServerSocketChannel的构造函数传进来的SelectionKey.OP_ACCEPT
        //是个accept事件
        selectionKey.interestOps(interestOps | readInterestOp);
    }
}
```

小结:

--》端口绑定bind

--》触发active事件

--》服务端channe doBeginRead方法, 向selector注册accept事件，这样netty就可以接收新的连接

tip:

与(&)运算： 同为 1 才为1

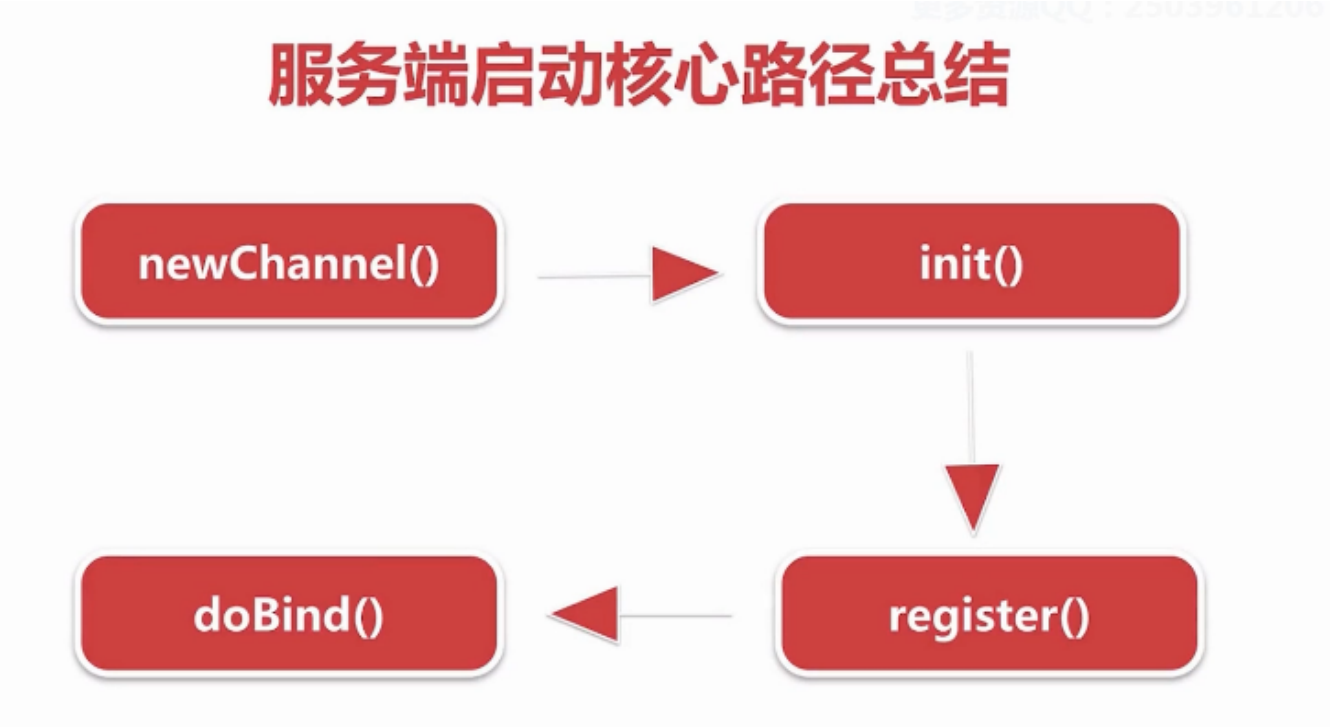
```
5 二进制 101
3 二进制 011
    结果 001
```

或(|)运算：有一个为1，则为1

```
5 二进制 101
3 二进制 011
    结果 111
```

异或(^)运算：不相同则为 1

```
5 二进制 101
3 二进制 011
    结果 110
```



四、NioEventLoop

4.1 思考三个问题

- 默认情况下，Netty服务端起多少线程？何时启动？
    - 2*cpu 调用execute方法时，判断当前线程是EventLoop线程，若是说明线程已启动，若是外部线程，则会调用startThread方法，判断当前线程是否启动，没有则启动当前线程。
- Netty如何解决JDK空轮询bug，避免cpu飙高的？

  超过512次，重新创建selector，并把原selector的所有的key移交到新的select or
- Netty如何保证异步串行无锁化？

  netty通过inEventLoop方法判断是外部线程，将所有操作封装成一个task丢到MpscQueue中，挨个执行。
    - 拿到客户端的一个channel，不需要对这个channel同步就可以进行多线程并发读写。
    - channelHandler中的所有操作都是线程安全的，不需要进行同步

4.2 NioEventLoop创建

- new NioEventLoopGroup(1) [线程组，默认 2*CPU]： 若不传构造参数，默认创建2倍cpu核心数的NioEventLoopGroup

```
protected MultithreadEventLoopGroup(int nThreads, Executor executor, Object... args)
{
    super(nThreads == 0 ? DEFAULT_EVENT_LOOP_THREADS : nThreads, executor, args);
}
```

- new ThreadPerTaskExecutor(newDefaultThreadFactory()) [线程创建器]：负责创建NioEventLoop底层对应的线程
    - 每次执行任务都会创建一个线程 : netty自己封装的FastThreadLocalThread，并非原生的线程。
    - NioEventLoop线程命名规则 nioEventLoop-1-xx
- for(){ new Child() } [构造NioEventLoop]
    - 保存线程执行器 ThreadPerTaskExecutor
    - 创建一个MpscQueue

      io.netty.channel.nio.NioEventLoopGroup#newChild

```
@Override
protected EventLoop newChild(Executor executor, Object... args) throws
Exception {
    return new NioEventLoop(this, executor, (SelectorProvider) args[0],
        ((SelectStrategyFactory) args[1]).newSelectStrategy(),
(RejectedExecutionHandler) args[2]);
}
```

```
protected SingleThreadEventLoop(EventLoopGroup parent, Executor executor,
                        boolean addTaskWakesUp, int maxPendingTasks,
                        RejectedExecutionHandler rejectedExecutionHandler) {
    super(parent, executor, addTaskWakesUp, maxPendingTasks,
rejectedExecutionHandler);
    tailTasks = newTaskQueue(maxPendingTasks);
}
```

io.netty.channel.nio.NioEventLoop#newTaskQueue

```
@Override
protected Queue<Runnable> newTaskQueue(int maxPendingTasks) {
    // This event loop never calls takeTask()
    //Mpsc MUltiply producer (外部线程)  single consumer (NioEventLoop线程)
    return PlatformDependent.newMpscQueue(maxPendingTasks);
}
```

```
/**
 * Create a new {@link Queue} which is safe to use for multiple producers
(different threads) and a single
 * consumer (one thread!).
 */
public static <T> Queue<T> newMpscQueue(final int maxCapacity) {
    return Mpsc.newMpscQueue(maxCapacity);
}
```

- 创建一个selector

```
NioEventLoop(NioEventLoopGroup parent, Executor executor, SelectorProvider
selectorProvider,
             SelectStrategy strategy, RejectedExecutionHandler
rejectedExecutionHandler) {
    super(parent, executor, false, DEFAULT_MAX_PENDING_TASKS,
rejectedExecutionHandler);
    if (selectorProvider == null) {
        throw new NullPointerException("selectorProvider");
    }
    if (strategy == null) {
        throw new NullPointerException("selectStrategy");
    }
    provider = selectorProvider;
    //一个selector和一个NioEventLoop绑定
```

```
        selector = openSelector();
        selectStrategy = strategy;
    }
```

- chooserFactory.newChooser(children) [线程选择器]：为每一个新连接，分配NioEventLoop线程

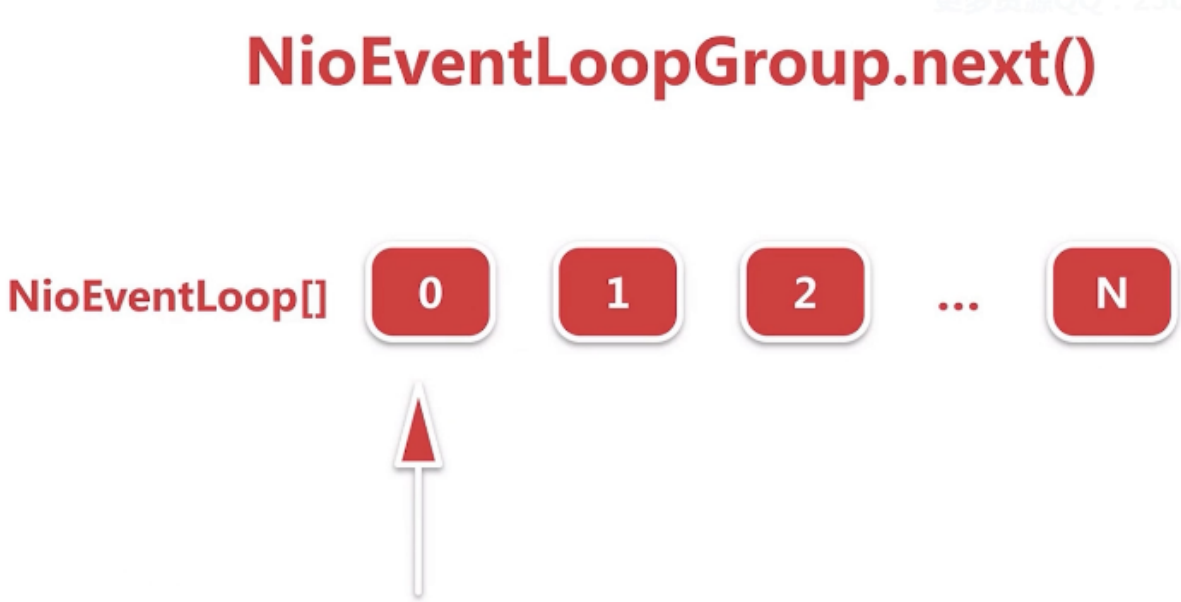
  io.netty.util.concurrent.MultithreadEventExecutorGroup#next

  第1个连接进来的时候选择第1个nioEventLoop进行绑定

  .....

  第n个连接进来的时候选择第n个nioEventLoop进行绑定

  第n+1个连接进来的时候选择第1个nioEventLoop进行绑定,循环进行



netty经过优化：与运算实现循环取数组下标，要比取模运算高效的多,因为在计算机底层，与运算是二进制的运算。

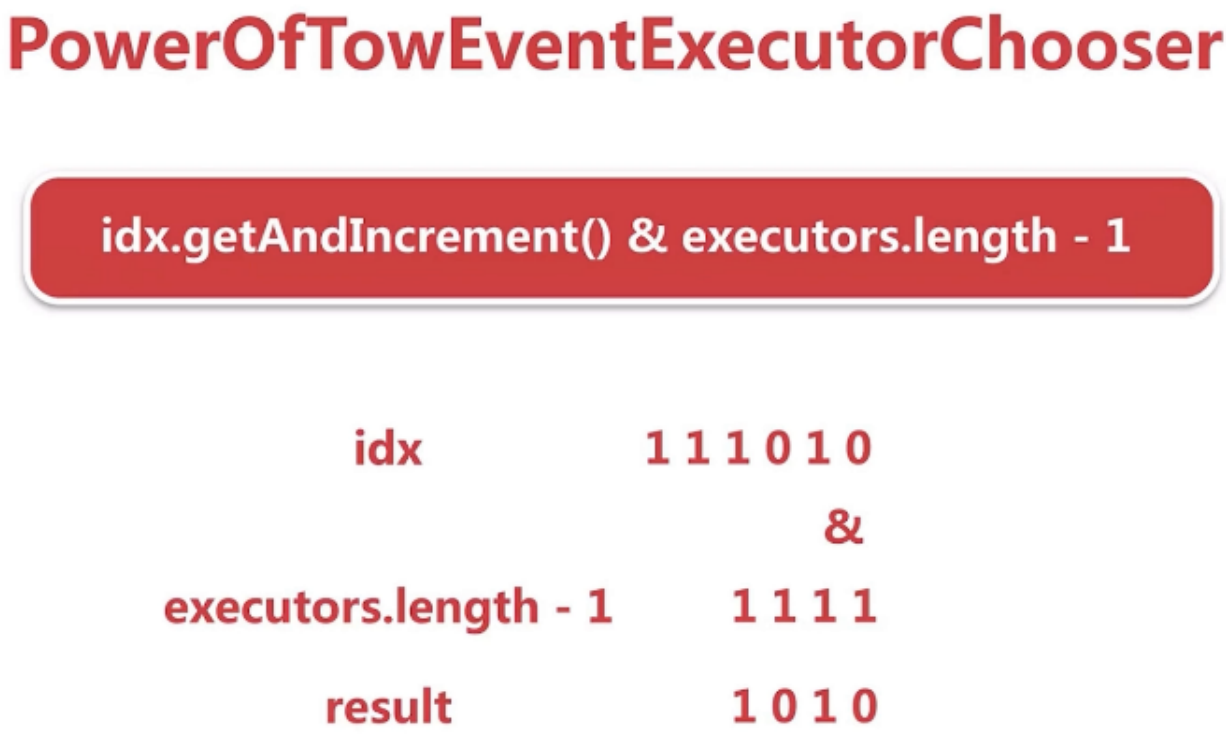

```
public EventExecutorChooser newChooser(EventExecutor[] executors) {
    if (isPowerOfTwo(executors.length)) {
        return new PowerOfTowEventExecutorChooser(executors);
    } else {
        return new GenericEventExecutorChooser(executors);
    }
}
```

io.netty.util.concurrent.DefaultEventExecutorChooserFactory.GenericEventExecutorChooser#next

```
    @Override
    public EventExecutor next() {
        return executors[Math.abs(idx.getAndIncrement() % executors.length)];
    }
```

io.netty.util.concurrent.DefaultEventExecutorChooserFactory.PowerOfTowEventExecutorChooser#next

```
public EventExecutor next() {
    return executors[idx.getAndIncrement() & executors.length - 1];
}
```



4.3 NioEventLoop启动流程

NioEventLoop启动两大触发器：

- 服务端启动绑定端口
    - 服务端将具体绑定端口的操作封装成一个task，调用NioEventLoop的execute方法
    - netty判断调用execute方法的线程是否是Nio线程，若不是，调用startThread()方法尝试创建线程。
    - 通过线程执行器 ThreadPerTaskExecutor创建nio线程 - FastThreadLocalThread
    - NioEventLoop对象会将创建的线程保存，目的是为了：判断后续对NioEventLoop相关的执行线程是否是本身，若不是，就封装成一个task，扔到一个taskQueue中串行执行，保证线程安全
    - 调用驱动NioEventLoop运转的核心方法：run()


```
io.netty.bootstrap.AbstractBootstrap#doBind0
private static void doBind0(
    ......
    channel.eventLoop().execute(new Runnable() {
        @Override
        public void run() {
            if (regFuture.isSuccess()) {
                channel.bind(localAddress,
promise).addListener(ChannelFutureListener.CLOSE_ON_FAILURE);
            } else {
                promise.setFailure(regFuture.cause());
            }
        }
    });
```

```
io.netty.util.concurrent.SingleThreadEventExecutor#execute
@Override
public void execute(Runnable task) {
    if (task == null) {
        throw new NullPointerException("task");
    }
    boolean inEventLoop = inEventLoop();
    if (inEventLoop) {
        addTask(task);
    } else {
        startThread();
        addTask(task);
        if (isShutdown() && removeTask(task)) {
            reject();
        }
    }
```

```
    if (!addTaskWakesUp && wakesUpForTask(task)) {
        wakeup(inEventLoop);
    }
}
```

```
io.netty.util.concurrent.AbstractEventExecutor#inEventLoop
判断线程是否是EventLoop线程
@Override
public boolean inEventLoop() {
    return inEventLoop(Thread.currentThread());
}
```

```
io.netty.util.concurrent.SingleThreadEventExecutor#inEventLoop
io.netty.util.concurrent.SingleThreadEventExecutor#thread

private volatile Thread thread;
@Override
public boolean inEventLoop(Thread thread) {
    return thread == this.thread;
}
```

```
private void startThread() {
    if (STATE_UPDATER.get(this) == ST_NOT_STARTED) {
        if (STATE_UPDATER.compareAndSet(this, ST_NOT_STARTED, ST_STARTED)) {
            doStartThread();
        }
    }
}
```

```
private void doStartThread() {
    assert thread == null;
    executor.execute(new Runnable() {
        @Override
        public void run() {
            thread = Thread.currentThread();
            if (interrupted) {
                thread.interrupt();
            }

            boolean success = false;
            updateLastExecutionTime();
            try {
                SingleThreadEventExecutor.this.run();
                success = true;
            } catch (Throwable t) {
                logger.warn("Unexpected exception from an event executor: ", t);
            } finally {
                for (;;) {
                    int oldState =
STATE_UPDATER.get(SingleThreadEventExecutor.this);
                    if (oldState >= ST_SHUTTING_DOWN || STATE_UPDATER.compareAndSet(
```

```
                            SingleThreadEventExecutor.this, oldState,
ST_SHUTTING_DOWN)) {
                        break;
                    }
                }

                // Check if confirmShutdown() was called at the end of the loop.
                if (success && gracefulShutdownStartTime == 0) {
                    logger.error("Buggy " + EventExecutor.class.getSimpleName() + "
implementation; " +
                            SingleThreadEventExecutor.class.getSimpleName() +
".confirmShutdown() must be called " +
                            "before run() implementation terminates.");
                }

                try {
                    // Run all remaining tasks and shutdown hooks.
                    for (;;) {
                        if (confirmShutdown()) {
                            break;
                        }
                    }
                } finally {
                    try {
                        cleanup();
                    } finally {
                        STATE_UPDATER.set(SingleThreadEventExecutor.this,
ST_TERMINATED);
                        threadLock.release();
                        if (!taskQueue.isEmpty()) {
                            logger.warn(
                                    "An event executor terminated with " +
                                            "non-empty task queue (" +
taskQueue.size() + ')');
                        }

                        terminationFuture.setSuccess(null);
                    }
                }
            }
        }
    });
}
```

4.4 NioEventLoop执行逻辑 （底层干了哪些事情，如何保证高效运转）

NioEventLoop 执行逻辑：

for循环体做三件事情：

---》调用select方法轮询注册到selector上的连接的i/o事件

---》调用processSelectedKeys()处理轮询出来的i/o事件

---》调用runAllTasks()方法处理外部线程扔到taskQueue中的任务

```
@Override
protected void run() {
    for (;;) {
        try {
            switch (selectStrategy.calculateStrategy(selectNowSupplier, hasTasks()))
{
                case SelectStrategy.CONTINUE:
                    continue;
                case SelectStrategy.SELECT:
                    select(wakenUp.getAndSet(false));
                    if (wakenUp.get()) {
                        selector.wakeup();
                    }
                default:
                    // fallthrough
            }

            cancelledKeys = 0;
            needsToSelectAgain = false;
            //默认50，处理i/o事件和运行任务时间是1 ： 1
            final int ioRatio = this.ioRatio;
            if (ioRatio == 100) {
                try {
                    processSelectedKeys();
                } finally {
```

```
                    // Ensure we always run tasks.
                    runAllTasks();
                }
            } else {
                final long ioStartTime = System.nanoTime();
                try {
                    processSelectedKeys();
                } finally {
                    // Ensure we always run tasks.
                    final long ioTime = System.nanoTime() - ioStartTime;
                    runAllTasks(ioTime * (100 - ioRatio) / ioRatio);
                }
            }
        } catch (Throwable t) {
            handleLoopException(t);
        }
        // Always handle shutdown even if the loop processing threw an exception.
        try {
            if (isShuttingDown()) {
                closeAll();
                if (confirmShutdown()) {
                    return;
                }
            }
        } catch (Throwable t) {
            handleLoopException(t);
        }
    }
}
```

- **检测i/o事件，select方法执行逻辑**
    - deadline及任务穿插逻辑处理
        - select操作进行deadline处理，判断如果当前有任务在taskQueue里面就终止本次select操作
    - 阻塞式select
        - 如果没有到截止时间并且taskQueue没有任务，就进行阻塞式select操作
    - 避免jdk空轮询bug
        - 阻塞式select操作结束之后，判断这次select操作是否真的阻塞这么长时间，如果没有阻塞这么长时间，则表示可能触发了jdk nio空轮询的bug，接下来netty判断触发空轮询次数是否达到一定的阈值（512），如果达到阈值，就通过替换原来select操作的方式，巧妙的避开了空轮询的bug

io.netty.channel.nio.NioEventLoop#select

```
private void select(boolean oldWakenUp) throws IOException {
    Selector selector = this.selector;
    try {
        int selectCnt = 0;
        long currentTimeNanos = System.nanoTime();
        long selectDeadLineNanos = currentTimeNanos +
delayNanos(currentTimeNanos);
```

```
        for (;;) {
            long timeoutMillis = (selectDeadLineNanos - currentTimeNanos +
500000L) / 1000000L;
            if (timeoutMillis <= 0) {
                if (selectCnt == 0) {
                    selector.selectNow();
                    selectCnt = 1;
                }
                break;
            }
            if (hasTasks() && wakenUp.compareAndSet(false, true)) {
                selector.selectNow();
                selectCnt = 1;
                break;
            }
            int selectedKeys = selector.select(timeoutMillis);
            selectCnt ++;

            if (selectedKeys != 0 || oldWakenUp || wakenUp.get() ||
hasTasks() || hasScheduledTasks()) {
                break;
            }
            if (Thread.interrupted()) {
                if (logger.isDebugEnabled()) {
                    logger.debug("Selector.select() returned prematurely
because " +
                            "Thread.currentThread().interrupt() was called.
Use " +
                            "NioEventLoop.shutdownGracefully() to shutdown
the NioEventLoop.");
                }
                selectCnt = 1;
                break;
            }

            long time = System.nanoTime();
            if (time - TimeUnit.MILLISECONDS.toNanos(timeoutMillis) >=
currentTimeNanos) {
                // timeoutMillis elapsed without anything selected.
                selectCnt = 1;
            } else if (SELECTOR_AUTO_REBUILD_THRESHOLD > 0 &&
                    selectCnt >= SELECTOR_AUTO_REBUILD_THRESHOLD) {
                logger.warn(
                        "Selector.select() returned prematurely {} times in a
row; rebuilding Selector {}.",
                        selectCnt, selector);

                rebuildSelector();
                selector = this.selector;
                // Select again to populate selectedKeys.
                selector.selectNow();
                selectCnt = 1;
                break;
```

```
            }
            currentTimeNanos = time;
        }

        if (selectCnt > MIN_PREMATURE_SELECTOR_RETURNS) {
            if (logger.isDebugEnabled()) {
                logger.debug("Selector.select() returned prematurely {} times
in a row for Selector {}.",
                        selectCnt - 1, selector);
            }
        }
    } catch (CancelledKeyException e) {
        if (logger.isDebugEnabled()) {
            logger.debug(CancelledKeyException.class.getSimpleName() + "
raised by a Selector {} - JDK bug?",
                    selector, e);
        }
    }
}
```

io.netty.channel.nio.NioEventLoop#rebuildSelector

```
public void rebuildSelector() {
    if (!inEventLoop()) {
        execute(new Runnable() {
            @Override
            public void run() {
                rebuildSelector();
            }
        });
        return;
    }

    final Selector oldSelector = selector;
    final Selector newSelector;

    if (oldSelector == null) {
        return;
    }

    try {
        newSelector = openSelector();
    } catch (Exception e) {
        logger.warn("Failed to create a new Selector.", e);
        return;
    }

    // Register all channels to the new Selector.
    int nChannels = 0;
    for (;;) {
        try {
            for (SelectionKey key: oldSelector.keys()) {
                Object a = key.attachment();
```

```
                try {
                    if (!key.isValid() || key.channel().keyFor(newSelector)
!= null) {
                        continue;
                    }

                    int interestOps = key.interestOps();
                    key.cancel();
                    SelectionKey newKey = key.channel().register(newSelector,
interestOps, a);
                    if (a instanceof AbstractNioChannel) {
                        // Update SelectionKey
                        ((AbstractNioChannel) a).selectionKey = newKey;
                    }
                    nChannels ++;
                } catch (Exception e) {
                    logger.warn("Failed to re-register a Channel to the new
Selector.", e);
                    if (a instanceof AbstractNioChannel) {
                        AbstractNioChannel ch = (AbstractNioChannel) a;
                        ch.unsafe().close(ch.unsafe().voidPromise());
                    } else {
                        @SuppressWarnings("unchecked")
                        NioTask<SelectableChannel> task =
(NioTask<SelectableChannel>) a;
                        invokeChannelUnregistered(task, key, e);
                    }
                }
            }
        } catch (ConcurrentModificationException e) {
            // Probably due to concurrent modification of the key set.
            continue;
        }

        break;
    }

    selector = newSelector;

    try {
        // time to close the old selector as everything else is registered to
the new one
        oldSelector.close();
    } catch (Throwable t) {
        if (logger.isWarnEnabled()) {
            logger.warn("Failed to close the old Selector.", t);
        }
    }

    logger.info("Migrated " + nChannels + " channel(s) to the new
Selector.");
}
```

io.netty.channel.nio.NioEventLoop#openSelector

```
private Selector openSelector() {
    final Selector selector;
    try {
        //调用jdkApi创建selector
        selector = provider.openSelector();
    } catch (IOException e) {
        throw new ChannelException("failed to open a new selector", e);
    }
    //如果不需要优化，直接返回原生selector
    if (DISABLE_KEYSET_OPTIMIZATION) {
        return selector;
    }
    //SelectedSelectionKeySet 底层是用数组 + keySize的方式实现的
    final SelectedSelectionKeySet selectedKeySet = new
SelectedSelectionKeySet();

    Object maybeSelectorImplClass = AccessController.doPrivileged(new
PrivilegedAction<Object>() {
        @Override
        public Object run() {
            try {
                return Class.forName(
                        "sun.nio.ch.SelectorImpl",
                        false,
                        PlatformDependent.getSystemClassLoader());
            } catch (ClassNotFoundException e) {
                return e;
            } catch (SecurityException e) {
                return e;
            }
        }
    });

    if (!(maybeSelectorImplClass instanceof Class) ||
            // ensure the current selector implementation is what we can
instrument.
            !((Class<?>)
maybeSelectorImplClass).isAssignableFrom(selector.getClass())) {
        if (maybeSelectorImplClass instanceof Exception) {
            Exception e = (Exception) maybeSelectorImplClass;
            logger.trace("failed to instrument a special java.util.Set into:
{}", selector, e);
        }
        return selector;
    }
    final Class<?> selectorImplClass = (Class<?>) maybeSelectorImplClass;
    Object maybeException = AccessController.doPrivileged(new
PrivilegedAction<Object>() {
        @Override
        public Object run() {
            try {
```

```
                Field selectedKeysField =
selectorImplClass.getDeclaredField("selectedKeys");
                Field publicSelectedKeysField =
selectorImplClass.getDeclaredField("publicSelectedKeys");

                selectedKeysField.setAccessible(true);
                publicSelectedKeysField.setAccessible(true);

                selectedKeysField.set(selector, selectedKeySet);
                publicSelectedKeysField.set(selector, selectedKeySet);
                return null;
            } catch (NoSuchFieldException e) {
                return e;
            } catch (IllegalAccessException e) {
                return e;
            } catch (RuntimeException e) {
                // JDK 9 can throw an inaccessible object exception here;
since Netty compiles
                // against JDK 7 and this exception was only added in JDK 9,
we have to weakly
                // check the type
                if
("java.lang.reflect.InaccessibleObjectException".equals(e.getClass().getName(
))) {
                    return e;
                } else {
                    throw e;
                }
            }
        }
    });
    if (maybeException instanceof Exception) {
        selectedKeys = null;
        Exception e = (Exception) maybeException;
        logger.trace("failed to instrument a special java.util.Set into: {}",
selector, e);
    } else {
        selectedKeys = selectedKeySet;
        logger.trace("instrumented a special java.util.Set into: {}",
selector);
    }
    return selector;
}
```

java.lang.Class#isAssignableFrom 判断是否是一个类的实现

- **处理i/o事件，processSelectedKeys执行逻辑**

  select操作每次都会把已经就绪状态的i/o事件，放到底层一个HashSet的数据结构中。

  netty默认情况下，会通过反射将select底层的HashSet转换成数组的方式进行优化，

  在处理每一个Keyset的时候，都会拿到对应的一个attachment，这个attachment就是

向selector注册i/o事件的时候绑定的经过netty封装之后的channel。

- selected keySet优化
  - 用数组替换select HashSet的实现，做到add方法时间复杂度为o(1)
- processSelectedKeysOptimized()
  - 真正处理I/O事件

```
private void processSelectedKeysOptimized(SelectionKey[] selectedKeys) {
    for (int i = 0;; i ++) {
        final SelectionKey k = selectedKeys[i];
        if (k == null) {
            break;
        }
        // null out entry in the array to allow to have it GC'ed once the
Channel close
        // See https://github.com/netty/netty/issues/2363
        selectedKeys[i] = null;

        final Object a = k.attachment();

        if (a instanceof AbstractNioChannel) {
            processSelectedKey(k, (AbstractNioChannel) a);
        } else {
            @SuppressWarnings("unchecked")
            NioTask<SelectableChannel> task = (NioTask<SelectableChannel>) a;
            processSelectedKey(k, task);
        }

        if (needsToSelectAgain) {
            // null out entries in the array to allow to have it GC'ed once
the Channel close
            // See https://github.com/netty/netty/issues/2363
            for (;;) {
                i++;
                if (selectedKeys[i] == null) {
                    break;
                }
                selectedKeys[i] = null;
            }

            selectAgain();
            // Need to flip the optimized selectedKeys to get the right
reference to the array
            // and reset the index to -1 which will then set to 0 on the for
loop
            // to start over again.
            //
            // See https://github.com/netty/netty/issues/1523
            selectedKeys = this.selectedKeys.flip();
            i = -1;
        }
```

```
        }
    }
```

io.netty.channel.nio.NioEventLoop#processSelectedKey(java.nio.channels.SelectionKey, io.netty.channel.nio.AbstractNioChannel)

```
private void processSelectedKey(SelectionKey k, AbstractNioChannel ch) {
    final AbstractNioChannel.NioUnsafe unsafe = ch.unsafe();
    if (!k.isValid()) {
        final EventLoop eventLoop;
        try {
            eventLoop = ch.eventLoop();
        } catch (Throwable ignored) {
            // If the channel implementation throws an exception because there is no
event loop, we ignore this
            // because we are only trying to determine if ch is registered to this
event loop and thus has authority
            // to close ch.
            return;
        }
        // Only close ch if ch is still registerd to this EventLoop. ch could have
deregistered from the event loop
        // and thus the SelectionKey could be cancelled as part of the
deregistration process, but the channel is
        // still healthy and should not be closed.
        // See https://github.com/netty/netty/issues/5125
        if (eventLoop != this || eventLoop == null) {
            return;
        }
        // close the channel if the key is not valid anymore
        unsafe.close(unsafe.voidPromise());
        return;
    }

    try {
        //读取事件
        int readyOps = k.readyOps();
        // We first need to call finishConnect() before try to trigger a read(...)
or write(...) as otherwise
        // the NIO JDK channel implementation may throw a NotYetConnectedException.
        if ((readyOps & SelectionKey.OP_CONNECT) != 0) {
            // remove OP_CONNECT as otherwise Selector.select(..) will always return
without blocking
            // See https://github.com/netty/netty/issues/924
            int ops = k.interestOps();
            ops &= ~SelectionKey.OP_CONNECT;
            k.interestOps(ops);

            unsafe.finishConnect();
        }
        // Process OP_WRITE first as we may be able to write some queued buffers and
so free memory.
        if ((readyOps & SelectionKey.OP_WRITE) != 0) {
```

```
            // Call forceFlush which will also take care of clear the OP_WRITE once
there is nothing left to write
            ch.unsafe().forceFlush();
        }
        // Also check for readOps of 0 to workaround possible JDK bug which may
otherwise lead
        // to a spin loop
        if ((readyOps & (SelectionKey.OP_READ | SelectionKey.OP_ACCEPT)) != 0 ||
readyOps == 0) {
            unsafe.read();
            if (!ch.isOpen()) {
                // Connection already closed - no need to handle write.
                return;
            }
        }
    } catch (CancelledKeyException ignored) {
        unsafe.close(unsafe.voidPromise());
    }
}
```

- **runAllTask()执行逻辑**

  任务分为两种，普通任务和定时任务，netty执行这些任务的时候，首先会将定时任务聚合到普通任务队列中，再挨个执行这些任务，并且每执行64个任务之后，计算当前执行时间是否超过最大允许执行时间，如果超过，就直接中断，中断之后就执行下一次nioEventLoop的循环

  - task的分类和添加
  - 普通任务队列 MpscQueue
    - 定时任务队列

  io.netty.util.concurrent.AbstractScheduledEventExecutor#schedule(java.lang.Runnable, long, java.util.concurrent.TimeUnit)

```
public  ScheduledFuture<?> schedule(Runnable command, long delay, TimeUnit
unit) {
        ObjectUtil.checkNotNull(command, "command");
        ObjectUtil.checkNotNull(unit, "unit");
        if (delay < 0) {
            throw new IllegalArgumentException(
                    String.format("delay: %d (expected: >= 0)", delay));
        }
        return schedule(new ScheduledFutureTask<Void>(
                this, command, null,
ScheduledFutureTask.deadlineNanos(unit.toNanos(delay))));
    }

......
    <V> ScheduledFuture<V> schedule(final ScheduledFutureTask<V> task) {
        if (inEventLoop()) {
            scheduledTaskQueue().add(task);
        } else {
            //scheduledTaskQueue 是一个普通的PriorityQueue，非线程安全的
            //为了保证线程安全，将添加定时任务的操作也当作一个普通的task，来保证所有的定
```

时任务的操作都是在nioEventLoop中实现的

```
            execute(new Runnable() {
                @Override
                public void run() {
                    scheduledTaskQueue().add(task);
                }
            });
        }
        return task;
    }
```

- 任务的聚合

  io.netty.util.concurrent.SingleThreadEventExecutor#fetchFromScheduledTaskQueue

  定时任务队列排队机制

  io.netty.util.concurrent.ScheduledFutureTask#compareTo

```
public int compareTo(Delayed o) {
    if (this == o) {
        return 0;
    }

    ScheduledFutureTask<?> that = (ScheduledFutureTask<?>) o;
    long d = deadlineNanos() - that.deadlineNanos();
    if (d < 0) {
        return -1;
    } else if (d > 0) {
        return 1;
    } else if (id < that.id) {
        return -1;
    } else if (id == that.id) {
        throw new Error();
    } else {
        return 1;
    }
}
```

- reactor线程任务的执行

  io.netty.util.concurrent.SingleThreadEventExecutor#runAllTasks(long)

```
protected boolean runAllTasks(long timeoutNanos) {
    fetchFromScheduledTaskQueue();
    Runnable task = pollTask();
    if (task == null) {
        afterRunningAllTasks();
        return false;
    }

    final long deadline = ScheduledFutureTask.nanoTime() +
```

```
timeoutNanos;
    long runTasks = 0;
    long lastExecutionTime;
    for (;;) {
        safeExecute(task);

        runTasks ++;

        // Check timeout every 64 tasks because nanoTime() is
relatively expensive. 耗时的
        // XXX: Hard-coded value - will make it configurable if it is
really a problem.
        if ((runTasks & 0x3F) == 0) {
            lastExecutionTime = ScheduledFutureTask.nanoTime();
            if (lastExecutionTime >= deadline) {
                break;
            }
        }

        task = pollTask();
        if (task == null) {
            lastExecutionTime = ScheduledFutureTask.nanoTime();
            break;
        }
    }

    afterRunningAllTasks();
    this.lastExecutionTime = lastExecutionTime;
    return true;
}
```

- 新连接接入通过chooser绑定一个NioEventLoop

五. netty-新连接接入

5.1 netty 新连接接入概述及思考问题

1）netty是在哪里检测有新连接接入的

2）新连接是怎样注册到NioEventLoop线程的

NIO模型的多路复用，多个连接复用一个线程，对netty而言，就是NioEventLoop

5.2.1 检测新连接

新连接通过服务端channel绑定的selector轮询出accpet事件（即I/O事件）

5.2.2 创建NioSocketChannel

基于JDK nio的channel创建一个netty的nioSocketChannel，也就是客户端channel

5.2.3 分配线程及注册selector

netty给客户端channel分配NioEventLoop并把这条channel注册到NioEventLoop对应的selector上，至此这条channel后续相关的读写都由此NioEventLoop管理

5.2.4 向selector注册读事件

注册的过程和服务端启动注册的accept事件复用同一段逻辑

断点调试：启动服务端 ---》telnet 127.0.0.1 8888方式创建新的连接

小结：

在服务端channel的NioEventLoop run（）的 第二个过程：

--》NioEventLoop#processSelectedKey(SelectionKey, AbstractNioChannel) 检测出accept事件之后，

--》通过jdk的accept方法创建jdk的channel，

--》并包装成netty自定义的channel，

--》List readBuf 临时存放channnel，

--》此过程中通过Handle对象控制连接接入的速率，默认情况下一次性读取16个连接

io.netty.channel.nio.AbstractNioMessageChannel.NioMessageUnsafe#read

```
public void read() {
        assert eventLoop().inEventLoop();
        final ChannelConfig config = config();
        final ChannelPipeline pipeline = pipeline();
        final RecvByteBufAllocator.Handle allocHandle = unsafe().recvBufAllocHandle();
        allocHandle.reset(config);
        boolean closed = false;
        Throwable exception = null;
        try {
            try {
                do {
                    int localRead = doReadMessages(readBuf);
                    if (localRead == 0) {
                        break;
                    }
                    if (localRead < 0) {
```

```
                        closed = true;
                        break;
                    }

                    allocHandle.incMessagesRead(localRead);
                } while (allocHandle.continueReading());
            } catch (Throwable t) {
                exception = t;
            }

            int size = readBuf.size();
            for (int i = 0; i < size; i ++) {
                readPending = false;
                pipeline.fireChannelRead(readBuf.get(i));
            }
            readBuf.clear();
            allocHandle.readComplete();
            pipeline.fireChannelReadComplete();

            if (exception != null) {
                closed = closeOnReadError(exception);

                pipeline.fireExceptionCaught(exception);
            }

            if (closed) {
                inputShutdown = true;
                if (isOpen()) {
                    close(voidPromise());
                }
            }
        } finally {
            // See https://github.com/netty/netty/issues/2254
            if (!readPending && !config.isAutoRead()) {
                removeReadOp();
            }
        }
    }
}
```

客户端channel创建完成之后，将服务端channel和客户端channel作为参数传递到NioSocketChannel的构造函数中，接下来进行一系列的创建过程。

```
// this 代表创建客户端channel的服务端nioServerSocketChannel（通过反射创建）  ch 代表jdk accept创建的channel
//new NioSocketChannel 构造出来的netty的客户端channel
new NioSocketChannel(this, ch);
...
public NioSocketChannel(Channel parent, SocketChannel socket) {
        super(parent, socket);
        config = new NioSocketChannelConfig(this, socket.socket());
    }
```

NioSocketChannel的构造函数是入口。做两件事情：

- 逐层调用父类的构造函数
    - 配置此channel为非阻塞，将感兴趣的读事件OP_READ,保存到成员变量方便后续注册到selector上

```
protected AbstractNioChannel(Channel parent, SelectableChannel ch, int readInterestOp) {
    super(parent);
    this.ch = ch;
    this.readInterestOp = readInterestOp;
    try {
        ch.configureBlocking(false);
    } catch (IOException e) {
        try {
            ch.close();
```

```
        } catch (IOException e2) {
            if (logger.isWarnEnabled()) {
                logger.warn(
                        "Failed to close a partially initialized socket.",
e2);
            }
        }
        throw new ChannelException("Failed to enter non-blocking mode.", e);
    }
}
```

- 创建和此channel相关的一些组件 id 作为channel的唯一标识 unsafe作为底层数据读写 pipeline作为业务逻辑的载体。

```
protected AbstractChannel(Channel parent) {
    this.parent = parent;
    id = newId();
    unsafe = newUnsafe();
    pipeline = newChannelPipeline();
}
```

- 创建一个和NioSocketChannel绑定的配置类
  - 设置此channel tcpNoDeply为 true，禁止negle算法（使小的数据包集合成大的数据包再发送出去），保证小的数据包尽可能发出去，降低延时

```
public DefaultSocketChannelConfig(SocketChannel channel, Socket javaSocket) {
    super(channel);
    if (javaSocket == null) {
        throw new NullPointerException("javaSocket");
    }
    this.javaSocket = javaSocket;

    // Enable TCP_NODELAY by default if possible.
    if (PlatformDependent.canEnableTcpNoDelayByDefault()) {
        try {
            setTcpNoDelay(true);
        } catch (Exception e) {
            // Ignore.
        }
    }
}
```

思考：与创建服务端channel不同的是，服务端channel是利用反射创建，而这里直接使用new 关键词，netty为什么这么设计?

5.3 Netty中channel的分类

- NioServerSocketChannel
  - Netty服务端channel的创建：用户代码传进来一个class类，netty拿到这个类通过反射方式创建。
- NioSocketChannel

    - 新连接接入过程中，拿到jdk底层创建的channel之后，通过显式的new关键字创建客户端channel
- unsafe
    - 用于实现每一种channel底层具体的协议

5.3.1 netty中channel的层级关系

io.netty.channel.Channel：

```
A nexus to a network socket or a component which is capable of I/O
* operations such as read, write, connect, and bind.
```

io.netty.channel.AbstractChannel

```
A skeletal {@link Channel} implementation.
...
    private final Channel parent;
    private final ChannelId id;
    private final Unsafe unsafe;
    private final DefaultChannelPipeline pipeline;
...
    private volatile EventLoop eventLoop;
```

io.netty.channel.nio.AbstractNioChannel

使用select轮询的的方式进行读写事件的监听

抽象出来，只关心I/O事件

```
 Abstract base class for {@link Channel} implementations which use a Selector based
approach.
     ...
    private final SelectableChannel ch;
    protected final int readInterestOp;
    volatile SelectionKey selectionKey;

    ...
    protected AbstractNioChannel(Channel parent, SelectableChannel ch, int readInterestOp) {
        super(parent);
        this.ch = ch;
        this.readInterestOp = readInterestOp;
        try {
            ch.configureBlocking(false);
        } catch (IOException e) {
         ...
```

io.netty.channel.nio.AbstractNioByteChannel

io.netty.channel.nio.AbstractNioByteChannel#AbstractNioByteChannel

```
protected AbstractNioByteChannel(Channel parent, SelectableChannel ch) {
    super(parent, ch, SelectionKey.OP_READ);
}
```

客户端channel： 创建的时候调用父类AbstractNioChannel 的构造函数，传递 read事件（I/O事件） 读取数据

```
{@link AbstractNioChannel} base class for {@link Channel}s that operate on bytes.
...
public final void read() {
        final ChannelConfig config = config();
        final ChannelPipeline pipeline = pipeline();
        final ByteBufAllocator allocator = config.getAllocator();
        final RecvByteBufAllocator.Handle allocHandle = recvBufAllocHandle();
        allocHandle.reset(config);
        ByteBuf byteBuf = null;
        boolean close = false;
        try {
            do {
                byteBuf = allocHandle.allocate(allocator);
                //读取字节数据
                allocHandle.lastBytesRead(doReadBytes(byteBuf));
                ...
            } while (allocHandle.continueReading());
                ...
}
```

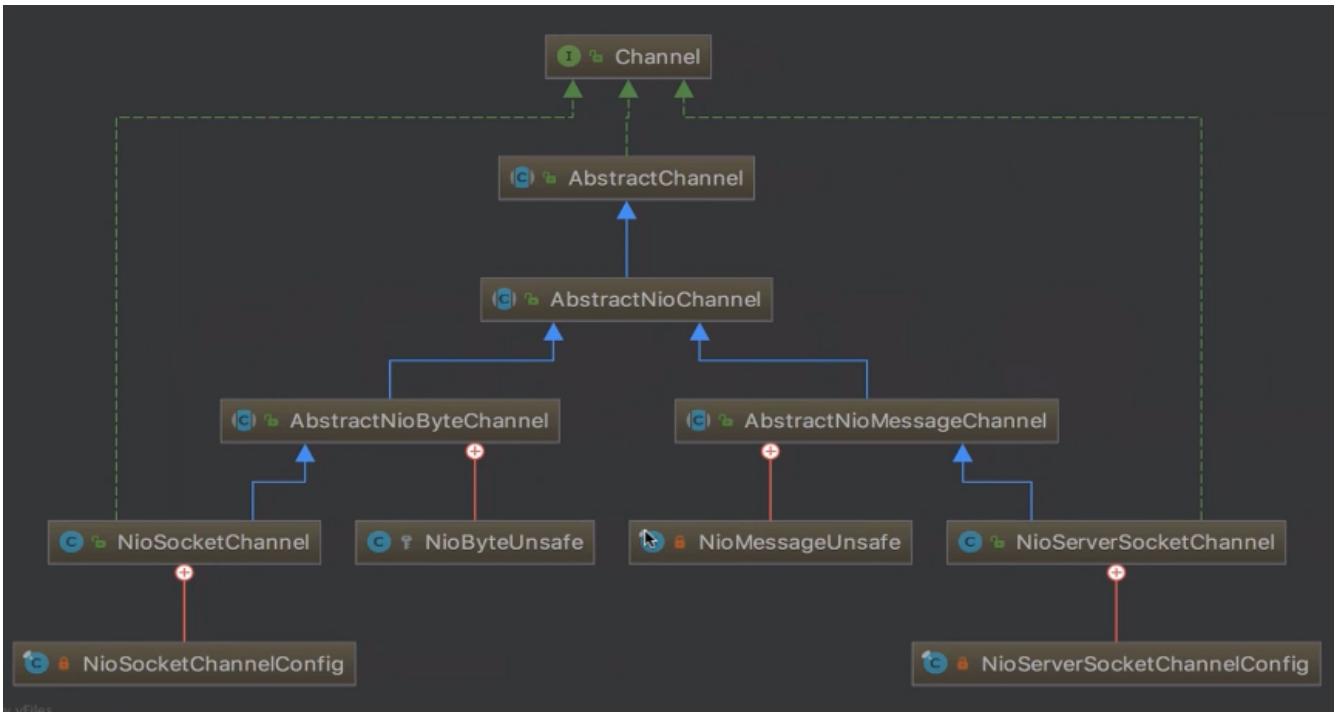
io.netty.channel.nio.AbstractNioMessageChannel

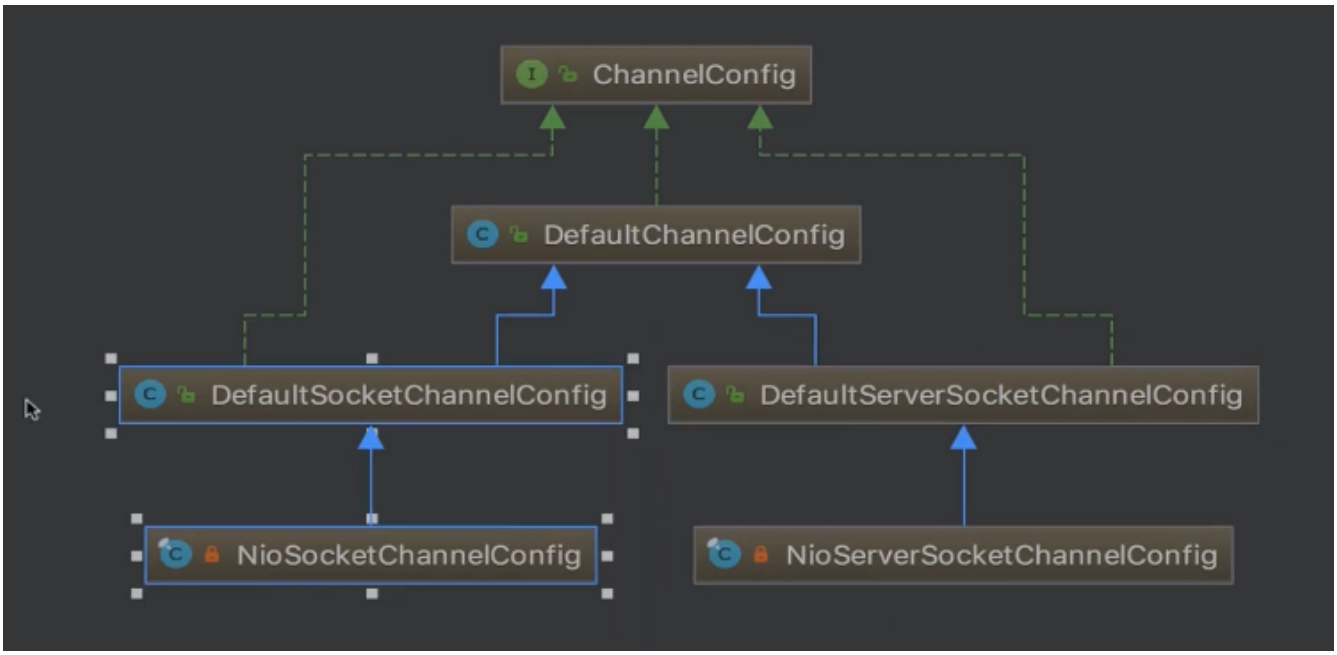
服务端channel：创建的时候调用父类AbstractNioChannel 的构造函数，传递accept事件（I/O事件），监听连接

```
* {@link AbstractNioChannel} base class for {@link Channel}s that operate on messages.

    public void read() {
            assert eventLoop().inEventLoop();
            final ChannelConfig config = config();
            final ChannelPipeline pipeline = pipeline();
            final RecvByteBufAllocator.Handle allocHandle = unsafe().recvBufAllocHandle();
            allocHandle.reset(config);
            boolean closed = false;
            Throwable exception = null;
            try {
                try {
                    do {
                        ...
                        int localRead = doReadMessages(readBuf);
                        ...
                        allocHandle.incMessagesRead(localRead);
                    } while (allocHandle.continueReading());
                } catch (Throwable t) {
                    exception = t;
                }
```

```
}
```





5.4 新连接 NioEventLoop分配和Selector注册

io.netty.channel.nio.AbstractNioMessageChannel.NioMessageUnsafe#read

--》io.netty.channel.nio.AbstractNioMessageChannel#doReadMessages 创建客户端channel

```
@Override
protected int doReadMessages(List<Object> buf) throws Exception {
    SocketChannel ch = javaChannel().accept();
    try {
        if (ch != null) {
            buf.add(new NioSocketChannel(this, ch));
            return 1;
        }
    } catch (Throwable t) {
     ...
    }
    return 0;
}
```

- --》io.netty.channel.ChannelPipeline#fireChannelRead for循环遍历每一条客户端连接，调用服务端channel的PipeLine的fireChannelRead 方法

```
...
for (int i = 0; i < size; i ++) {
    readPending = false;
    pipeline.fireChannelRead(readBuf.get(i));
}
...
```

- --》回顾netty服务端启动：io.netty.bootstrap.ServerBootstrap#init
- --》 服务端channel PipeLine的构成

服务端channel PipeLine传播channelRead事件会从head开始--ServerBootstrapAcceptor--最后到Tail

即 `pipeline.fireChannelRead(readBuf.get(i))` 会将每一条客户端连接通过fireChannelRead逐层传到ServerBootstrapAcceptor，即调用io.netty.bootstrap.ServerBootstrap.ServerBootstrapAcceptor#channelRead

- --》ServerBootstrapAcceptor#channelRead主要做以下几件事情
    - 添加childHandler
    - 设置options和attrs
    - 选择NioEventLoop并注册selector

```
public void channelRead(ChannelHandlerContext ctx, Object msg) {
    final Channel child = (Channel) msg;
    //这里的childHandler是以一个特殊的handler，即服务端启动时传进来的ChannelInitializer
    child.pipeline().addLast(childHandler);
    //childOptions 底层jdk读写相关的参数
    for (Entry<ChannelOption<?>, Object> e: childOptions) {
        try {
            if (!child.config().setOption((ChannelOption<Object>) e.getKey(), e.getValue()))
{
                logger.warn("Unknown channel option: " + e);
            }
        } catch (Throwable t) {
            logger.warn("Failed to set a channel option: " + child, t);
        }
    }
    //childAttrs 在客户端channel上绑定一些自定义的属性 如密钥 channel存活时间等
    for (Entry<AttributeKey<?>, Object> e: childAttrs) {
        child.attr((AttributeKey<Object>) e.getKey()).set(e.getValue());
    }

    try {
        // childGroup 是一个workGroup 注册的时候选择一个NioEventLoop进行注册
        childGroup.register(child).addListener(new ChannelFutureListener() {
            @Override
            public void operationComplete(ChannelFuture future) throws Exception {
                if (!future.isSuccess()) {
                    forceClose(child, future.cause());
                }
            }
        });
    } catch (Throwable t) {
        forceClose(child, t);
    }
}
```

io.netty.channel.ChannelInitializer#handlerAdded --》

io.netty.channel.ChannelInitializer#initChannel(io.netty.channel.ChannelHandlerContext)

```
private boolean initChannel(ChannelHandlerContext ctx) throws Exception {
    if (initMap.putIfAbsent(ctx, Boolean.TRUE) == null) { // Guard against re-entrance.
        try {
            //这里会回调到用户代码里的方法
ChannelInitializer#initChannel(io.netty.channel.socket.SocketChannel)
            initChannel((C) ctx.channel());
        } catch (Throwable cause) {
            // Explicitly call exceptionCaught(...) as we removed the handler before calling
initChannel(...).
            // We do so to prevent multiple calls to initChannel(...).
            exceptionCaught(ctx, cause);
        } finally {
```

```
            //调用remove将自身删除
            remove(ctx);
        }
        return true;
    }
    return false;
}
//这就是netty为新连接添加channelHandler的逻辑
```

io.netty.channel.EventLoopGroup#register(io.netty.channel.Channel)

```
io.netty.channel.MultithreadEventLoopGroup#register(io.netty.channel.Channel)
@Override
public ChannelFuture register(Channel channel) {
    return next().register(channel);
}
```

next()返回一个NioEventLoop

```
@Override
public EventLoop next() {
    return (EventLoop) super.next();
}
```

io.netty.util.concurrent.MultithreadEventExecutorGroup#next

```
@Override
public EventExecutor next() {
    return chooser.next();
}
```

客户端channel选择nioEventLoop并注册selector的过程

```
io.netty.channel.SingleThreadEventLoop#register(io.netty.channel.ChannelPromise)
@Override
public ChannelFuture register(final ChannelPromise promise) {
    ObjectUtil.checkNotNull(promise, "promise");
    promise.channel().unsafe().register(this, promise);
    return promise;
}
```

```
io.netty.channel.nio.AbstractNioChannel#doRegister
protected void doRegister() throws Exception {
    boolean selected = false;
    for (;;) {
        try {
            selectionKey = javaChannel().register(eventLoop().selector, 0, this);
            return;
```

```
        } catch (CancelledKeyException e) {
            if (!selected) {
                eventLoop().selectNow();
                selected = true;
            } else {
                throw e;
            }
        }
    }
}
```

小结：服务端channel在检测到新连接并且创建完客户端channel之后，会调用一个连接器做一些处理，

包括给客户端channel填充逻辑处理器channelHanler，配置options和attrs，选定一个NioEventLoop进行绑定，并把channel注册到NioEventLoop的selector上，这时不关心任何事件。

5.5 NioSocketChannel读事件的注册

io.netty.channel.AbstractChannel.AbstractUnsafe#register0

通过debug方式了解相应代码

io.netty.channel.DefaultChannelPipeline.HeadContext#channelActive

```
@Override
public void channelActive(ChannelHandlerContext ctx) throws Exception {
    //传播channelActive 事件
    ctx.fireChannelActive();

    readIfIsAutoRead();
}
```

```
private void readIfIsAutoRead() {
    if (channel.config().isAutoRead()) {//默认只要绑定端口就会接收连接，只要当前连接绑定到selector上就会自动读，即向selector上注册读事件
        channel.read();
    }
}
```

io.netty.channel.AbstractChannel#read

```
public Channel read() {
    pipeline.read();
    return this;
}
```

io.netty.channel.DefaultChannelPipeline#read

```
public final ChannelPipeline read() {
    tail.read();
    return this;
}
```

io.netty.channel.AbstractChannelHandlerContext#invokeRead

```
private void invokeRead() {
    if (invokeHandler()) {
        try {
            ((ChannelOutboundHandler) handler()).read(this);
        } catch (Throwable t) {
            notifyHandlerException(t);
        }
    } else {
        read();
    }
}
```

io.netty.channel.DefaultChannelPipeline.HeadContext#read

```
public void read(ChannelHandlerContext ctx) {
    unsafe.beginRead();
}
```

io.netty.channel.AbstractChannel.AbstractUnsafe#beginRead

```
public final void beginRead() {
    assertEventLoop();
    ...
    try {
        doBeginRead();
    } catch (final Exception e) {
    ...
    }
}
```

io.netty.channel.nio.AbstractNioChannel#doBeginRead

```
protected void doBeginRead() throws Exception {
    // Channel.read() or ChannelHandlerContext.read() was called
    final SelectionKey selectionKey = this.selectionKey;
    if (!selectionKey.isValid()) {
        return;
    }

    readPending = true;

    final int interestOps = selectionKey.interestOps();
    //readInterestOp 即创建nioSocketChannel时传进来的OP_READ
```

```
    if ((interestOps & readInterestOp) == 0) {
        selectionKey.interestOps(interestOps | readInterestOp);
    }
}
```

六. netty-PipeLine

PipeLine是netty的大动脉，主要负责读写事件的传播

6.1 思考问题

- netty是如何判断ChannelHandler类型的
    - 调用pipeline添加handlerContext节点的时候，根据instanceOf关键词，判断当前节点是inbound还是outbound类型，并用一个boolean类型的变量标识
- 对于ChannelHandler的添加应遵循什么样的顺序
    - inbound类型事件的传播与添加inboundHanler的顺序正相关
    - outbound类型事件的传播与添加outboundHanler的顺序正相关
- 用户手动触发事件传播，不同的触发方式有什么样的区别?
    - 通过channel触发时，从tail或head节点往下传播
    - 通过当前节点触发时，从当前节点开始往下传播

6.2 学习内容

- pipeLine的初始化
- 添加和删除ChannelHandler
- 事件和异常的传播

6.3 pipeLine的初始化

6.3.1 pipeline在创建channel的时候被创建

不管服务端channel还是客户端channel，都会调用abstractChannel的构造函数

io.netty.channel.AbstractChannel#AbstractChannel(io.netty.channel.Channel, io.netty.channel.ChannelId)

```
protected AbstractChannel(Channel parent, ChannelId id) {
    this.parent = parent;
    this.id = id;
    unsafe = newUnsafe();
    pipeline = newChannelPipeline();
}
```

io.netty.channel.DefaultChannelPipeline#DefaultChannelPipeline

```
protected DefaultChannelPipeline(Channel channel) {
    this.channel = ObjectUtil.checkNotNull(channel, "channel");
    succeededFuture = new SucceededChannelFuture(channel, null);
    voidPromise =  new VoidChannelPromise(channel, true);

    tail = new TailContext(this);
    head = new HeadContext(this);

    //通过next和prev将tail和head变成一个双向链表数据结构
    head.next = tail;
    tail.prev = head;
}
```

6.3.2 pipeline节点数据结构：ChannelHandlerContext

pipeline的每一个节点都是ChannelHandlerContext这种数据结构

```
public interface ChannelHandlerContext extends AttributeMap, ChannelInboundInvoker,
ChannelOutboundInvoker {
    /**
     * Return the {@link Channel} which is bound to the {@link ChannelHandlerContext}.
     */
    Channel channel();

    /**对应nioEventLoop
     * Returns the {@link EventExecutor} which is used to execute an arbitrary task.
     */
    EventExecutor executor();

    /**
     * The unique name of the {@link ChannelHandlerContext}.The name was used when then
{@link ChannelHandler}
     * was added to the {@link ChannelPipeline}. This name can also be used to access the
registered
     * {@link ChannelHandler} from the {@link ChannelPipeline}.
     */
    String name();

    /**
     * The {@link ChannelHandler} that is bound this {@link ChannelHandlerContext}.
     */
    ChannelHandler handler();

    /**
     * Return {@code true} if the {@link ChannelHandler} which belongs to this context was
removed
     * from the {@link ChannelPipeline}. Note that this method is only meant to be called
from with in the
     * {@link EventLoop}.
     */
    boolean isRemoved();

    @Override
```

```
    ChannelHandlerContext fireChannelRegistered();

    @Override
    ChannelHandlerContext fireChannelUnregistered();

    @Override
    ChannelHandlerContext fireChannelActive();

    @Override
    ChannelHandlerContext fireChannelInactive();

    @Override
    ChannelHandlerContext fireExceptionCaught(Throwable cause);

    @Override
    ChannelHandlerContext fireUserEventTriggered(Object evt);

    @Override
    ChannelHandlerContext fireChannelRead(Object msg);

    @Override
    ChannelHandlerContext fireChannelReadComplete();

    @Override
    ChannelHandlerContext fireChannelWritabilityChanged();

    @Override
    ChannelHandlerContext read();

    @Override
    ChannelHandlerContext flush();

    /**
     * Return the assigned {@link ChannelPipeline}
     */
    ChannelPipeline pipeline();

    /**内存分配器 : 当前节点有数据读写，分配bytebuf的时候用哪个内存分配器分配
     * Return the assigned {@link ByteBufAllocator} which will be used to allocate {@link
ByteBuf}s.
     */
    ByteBufAllocator alloc();

    /**
     * @deprecated Use {@link Channel#attr(AttributeKey)}
     */
    @Deprecated
    @Override
    <T> Attribute<T> attr(AttributeKey<T> key);

    /**
     * @deprecated Use {@link Channel#hasAttr(AttributeKey)}
     */
```

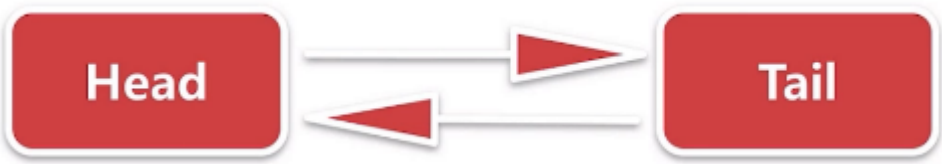
```
    @Deprecated
    @Override
    <T> boolean hasAttr(AttributeKey<T> key);
}
```

- io.netty.util.AttributeMap 存储自定义属性
- io.netty.channel.ChannelInboundInvoker 传播读事件
- io.netty.channel.ChannelOutboundInvoker 传播写事件
- ChannelHandlerContext 的默认实现 io.netty.channel.AbstractChannelHandlerContext
    - ```
      //pipeline的串行结构主要依赖于以下两个属性
      volatile AbstractChannelHandlerContext next;
      volatile AbstractChannelHandlerContext prev;
      ```

6.3.3 Pipeline两大哨兵 TailContext & HeadContext

Head节点 的unsafe负责实现channel的具体协议

Tail节点起到终止事件和异常传播的作用




```
protected DefaultChannelPipeline(Channel channel) {
    ...
    tail = new TailContext(this);
    head = new HeadContext(this);
    ...
}
```

- TailContext - inbound处理器
```

```
AbstractChannelHandlerContext(DefaultChannelPipeline pipeline, EventExecutor executor,
String name,boolean inbound, boolean outbound) {
    this.name = ObjectUtil.checkNotNull(name, "name");
    this.pipeline = pipeline;
    this.executor = executor;
    this.inbound = inbound;
    this.outbound = outbound;
    // Its ordered if its driven by the EventLoop or the given Executor is an instanceof
OrderedEventExecutor.
    ordered = executor == null || executor instanceof OrderedEventExecutor;
}
```

```
// A special catch-all handler that handles both bytes and messages.
final class TailContext extends AbstractChannelHandlerContext implements
ChannelInboundHandler {

    TailContext(DefaultChannelPipeline pipeline) {
        super(pipeline, null, TAIL_NAME, true, false);
        setAddComplete();//设置已添加标记
    }
    //业务逻辑处理器
    @Override
    public ChannelHandler handler() {
        return this;
    }

    @Override
    public void channelRegistered(ChannelHandlerContext ctx) throws Exception { }//空

    @Override
    public void channelUnregistered(ChannelHandlerContext ctx) throws Exception { }//空

    @Override
    public void channelActive(ChannelHandlerContext ctx) throws Exception { }//空

    @Override
    public void channelInactive(ChannelHandlerContext ctx) throws Exception { }//空

    @Override
    public void channelWritabilityChanged(ChannelHandlerContext ctx) throws Exception { }

    @Override
    public void handlerAdded(ChannelHandlerContext ctx) throws Exception { }//空

    @Override
    public void handlerRemoved(ChannelHandlerContext ctx) throws Exception { }//空

    @Override
    public void userEventTriggered(ChannelHandlerContext ctx, Object evt) throws Exception {
        // This may not be a configuration error and so don't log anything.
        // The event may be superfluous for the current pipeline configuration.
        ReferenceCountUtil.release(evt);
```

```
    }
    //发生异常时进行处理
    @Override
    public void exceptionCaught(ChannelHandlerContext ctx, Throwable cause) throws Exception
{
        onUnhandledInboundException(cause);
    }
    //传进来的消息未被处理时会触发
    @Override
    public void channelRead(ChannelHandlerContext ctx, Object msg) throws Exception {
        onUnhandledInboundMessage(msg);
    }

    @Override
    public void channelReadComplete(ChannelHandlerContext ctx) throws Exception { }
}
```

结论：TailHead主要做一些收尾的事情，如异常未处理好会给予警告，消息没处理会建议你处理

- HeadContext - outbound处理器

```
final class HeadContext extends AbstractChannelHandlerContext
        implements ChannelOutboundHandler, ChannelInboundHandler {
    //处理底层数据读写
    private final Unsafe unsafe;

    HeadContext(DefaultChannelPipeline pipeline) {
        super(pipeline, null, HEAD_NAME, false, true);
        unsafe = pipeline.channel().unsafe();
        setAddComplete();
    }

    @Override
    public ChannelHandler handler() {
        return this;
    }

    @Override
    public void handlerAdded(ChannelHandlerContext ctx) throws Exception {
        // NOOP
    }

    @Override
    public void handlerRemoved(ChannelHandlerContext ctx) throws Exception {
        // NOOP
    }

    @Override
    public void bind(
            ChannelHandlerContext ctx, SocketAddress localAddress, ChannelPromise
promise)
            throws Exception {
        unsafe.bind(localAddress, promise);
```

```
    }

    @Override
    public void connect(
            ChannelHandlerContext ctx,
            SocketAddress remoteAddress, SocketAddress localAddress,
            ChannelPromise promise) throws Exception {
        unsafe.connect(remoteAddress, localAddress, promise);
    }

    @Override
    public void disconnect(ChannelHandlerContext ctx, ChannelPromise promise) throws
Exception {
        unsafe.disconnect(promise);
    }

    @Override
    public void close(ChannelHandlerContext ctx, ChannelPromise promise) throws
Exception {
        unsafe.close(promise);
    }

    @Override
    public void deregister(ChannelHandlerContext ctx, ChannelPromise promise) throws
Exception {
        unsafe.deregister(promise);
    }

    @Override
    public void read(ChannelHandlerContext ctx) {
        unsafe.beginRead();
    }

    @Override
    public void write(ChannelHandlerContext ctx, Object msg, ChannelPromise promise)
throws Exception {
        unsafe.write(msg, promise);
    }

    @Override
    public void flush(ChannelHandlerContext ctx) throws Exception {
        unsafe.flush();
    }

    @Override
    public void exceptionCaught(ChannelHandlerContext ctx, Throwable cause) throws
Exception {
        ctx.fireExceptionCaught(cause);
    }

    @Override
    public void channelRegistered(ChannelHandlerContext ctx) throws Exception {
        invokeHandlerAddedIfNeeded();
```

```
        ctx.fireChannelRegistered();
    }

    @Override
    public void channelUnregistered(ChannelHandlerContext ctx) throws Exception {
        ctx.fireChannelUnregistered();

        // Remove all handlers sequentially if channel is closed and unregistered.
        if (!channel.isOpen()) {
            destroy();
        }
    }

    @Override
    public void channelActive(ChannelHandlerContext ctx) throws Exception {
        ctx.fireChannelActive();

        readIfIsAutoRead();
    }

    @Override
    public void channelInactive(ChannelHandlerContext ctx) throws Exception {
        ctx.fireChannelInactive();
    }

    @Override
    public void channelRead(ChannelHandlerContext ctx, Object msg) throws Exception
{
        ctx.fireChannelRead(msg);
    }

    @Override
    public void channelReadComplete(ChannelHandlerContext ctx) throws Exception {
        ctx.fireChannelReadComplete();

        readIfIsAutoRead();
    }

    private void readIfIsAutoRead() {
        if (channel.config().isAutoRead()) {
            channel.read();
        }
    }

    @Override
    public void userEventTriggered(ChannelHandlerContext ctx, Object evt) throws
Exception {
        ctx.fireUserEventTriggered(evt);
    }

    @Override
    public void channelWritabilityChanged(ChannelHandlerContext ctx) throws
Exception {
```

```
            ctx.fireChannelWritabilityChanged();
        }
    }
```

结论：HeadContext 主要做的事情：1) 往下传播读写事件：netty每次传播读写事件都会从Head开始

2）读写事件委托给 unsafe 进行读写

6.4 Pipeline 添加ChannelHandler

- 判断是否重复添加ChannelHandler
- 创建节点并添加至链表
    - 创建的节点就是ChannelHandlerContext，将ChannelHandler包装成ChannelHandlerContext添加到链表
- 回调添加完成事件
    - ChannelInitializer被添加完成之后会回调到用户代码（自己实现的initChannel()方法）

```
//用户代码 ChannelInitializer 是个抽象方法
bootstrap.group(bossGroup, workGroup)
        .channel(NioServerSocketChannel.class)
        .childOption(ChannelOption.TCP_NODELAY, true)
        .childAttr(AttributeKey.newInstance("childAttr"), "childAttrValue")
        .handler(new ServerHandler())
        .childHandler(new ChannelInitializer<SocketChannel>() {

            @Override
            protected void initChannel(SocketChannel ch) throws Exception {
                ch.pipeline().addLast(new ChannelInboundHandlerAdapter());
                ch.pipeline().addLast(new ChannelOutboundHandlerAdapter());
            }
        });
```

io.netty.channel.DefaultChannelPipeline#addLast(io.netty.util.concurrent.EventExecutorGroup, java.lang.String, io.netty.channel.ChannelHandler)

```
@Override
public final ChannelPipeline addLast(EventExecutorGroup group, String name, ChannelHandler
handler) {
    final AbstractChannelHandlerContext newCtx;
    synchronized (this) {
        // 判断是否重复添加
        checkMultiplicity(handler);
        // 创建节点
        newCtx = newContext(group, filterName(name, handler), handler);
        //并添加至链表
        addLast0(newCtx);

        // If the registered is false it means that the channel was not registered on an
eventloop yet.
```

```
        // In this case we add the context to the pipeline and add a task that will call
        // ChannelHandler.handlerAdded(...) once the channel is registered.
        if (!registered) {
            newCtx.setAddPending();
            callHandlerCallbackLater(newCtx, true);
            return this;
        }
        EventExecutor executor = newCtx.executor();

        if (!executor.inEventLoop()) {
            newCtx.setAddPending();
            //io.netty.util.concurrent.SingleThreadEventExecutor#execute 添加到Mpsc队列
            executor.execute(new Runnable() {
                @Override
                public void run() {
                    callHandlerAdded0(newCtx);
                }
            });
            return this;
        }
    }
    //
    callHandlerAdded0(newCtx);
    return this;
}
```

io.netty.channel.DefaultChannelPipeline#callHandlerAdded0

```
private void callHandlerAdded0(final AbstractChannelHandlerContext ctx) {
    try {
        //回调到用户代码:io.netty.channel.ChannelInitializer#handlerAdded
        ctx.handler().handlerAdded(ctx);
        //自旋 + CAS 设置已添加标记 ADD_COMPLETE
        ctx.setAddComplete();
    } catch (Throwable t) {
        boolean removed = false;
        try {
            //删除当前节点
            remove0(ctx);
            try {
                ctx.handler().handlerRemoved(ctx);
            } finally {
                ctx.setRemoved();
            }
            removed = true;
        } catch (Throwable t2) {
            if (logger.isWarnEnabled()) {
                logger.warn("Failed to remove a handler: " + ctx.name(), t2);
            }
        }
        ...
}
```

io.netty.channel.ChannelInitializer#handlerAdded

```
public void handlerAdded(ChannelHandlerContext ctx) throws Exception {
    if (ctx.channel().isRegistered()) {
        ...
        initChannel(ctx);
    }
}
```

io.netty.channel.ChannelInitializer#initChannel(C)

```
//抽象方法
protected abstract void initChannel(C ch) throws Exception;
```

6.5 删除ChannelHandler

6.5.1 应用场景 之 权限校验

```
public class AuthHandler extends SimpleChannelInboundHandler<ByteBuf> {

    @Override
    protected void channelRead0(ChannelHandlerContext ctx, ByteBuf msg) throws Exception {
        if (pass(msg)) {
            //校验通过将当前节点删除
            ctx.pipeline().remove(this);
        } else {
            //校验不通过直接关闭连接
            ctx.close();
        }
    }

    private boolean pass(ByteBuf password) {
        return false;
    }
}
```

6.5.2 删除过程

- 找到节点

  io.netty.channel.DefaultChannelPipeline#getContextOrDie(io.netty.channel.ChannelHandler)

  io.netty.channel.DefaultChannelPipeline#context(io.netty.channel.ChannelHandler)

  ```
  //通过遍历链表的方式找到ChannelHandler对应的ChannelHandlerContext
  public final ChannelHandlerContext context(ChannelHandler handler) {
      if (handler == null) {
          throw new NullPointerException("handler");
      }
      AbstractChannelHandlerContext ctx = head.next;
      for (;;) {
  ```

```
        if (ctx == null) {
            return null;
        }
        if (ctx.handler() == handler) {
            return ctx;
        }
        ctx = ctx.next;
    }
}
```

- 链表的删除

  io.netty.channel.DefaultChannelPipeline#remove(io.netty.channel.AbstractChannelHandlerContext)

```
//标准的链表删除节点方法
private static void remove0(AbstractChannelHandlerContext ctx) {
    AbstractChannelHandlerContext prev = ctx.prev;
    AbstractChannelHandlerContext next = ctx.next;
    prev.next = next;
    next.prev = prev;
}
```

- 回调删除Handler事件

  io.netty.channel.DefaultChannelPipeline#callHandlerRemoved0

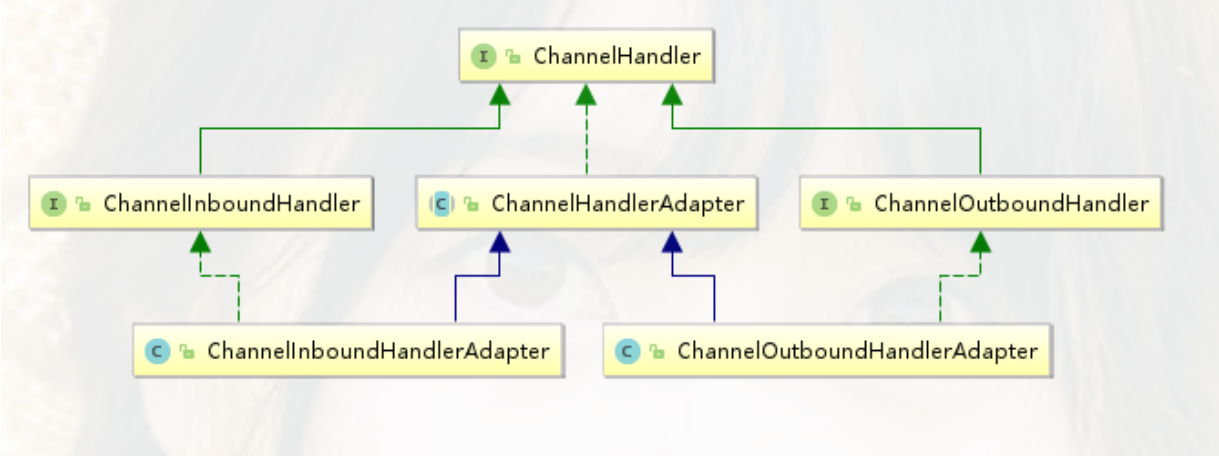
```
private void callHandlerRemoved0(final AbstractChannelHandlerContext ctx) {
    // Notify the complete removal.
    try {
        try {
            //这里会拿到当前节点的channelHandler，调用handlerRemoved方法，最终调用到回调方法
里面
            ctx.handler().handlerRemoved(ctx);
        } finally {
            //用户的回调方法执行结束之后，执行setRemoved方法
            ctx.setRemoved();
        }
    } catch (Throwable t) {
        fireExceptionCaught(new ChannelPipelineException(
                ctx.handler().getClass().getName() + ".handlerRemoved() has thrown
an exception.", t));
    }
}
```

6.6 inBound事件的传播

- 何为inBound事件以及ChannelInBoundHandler
- ChannelRead事件的传播
  - ChannelRead事件是典型的inbound事件
  - 按照添加handler的顺序传播

- SimpleInBoundHandler处理器
    - 自动释放bytebuf对象

netty中channelHandler接口的继承关系如图



最顶层接口 ChannelHandler

默认实现 ChannelHandlerAdapter

ChannelInboundHandler和ChannelOutboundHandler：

继承了ChannelHandler接口，分别定制了一些特殊的功能

平时用户代码编写channelHandler较多用到：

直接继承：ChannelInboundHandlerAdapter 和ChannelOutboundHandlerAdapter

ChannelInboundHandler在ChannelHandler基础上做了扩展：

```
public interface ChannelInboundHandler extends ChannelHandler {

    /**channel注册到nioEventLoop对应的selector后会回调到 ChannelHandler
     */
    void channelRegistered(ChannelHandlerContext ctx) throws Exception;

    void channelUnregistered(ChannelHandlerContext ctx) throws Exception;

    /**channel激活后的回调
     */
    void channelActive(ChannelHandlerContext ctx) throws Exception;

    /**channel失效的回调
     */
    void channelInactive(ChannelHandlerContext ctx) throws Exception;

    /**
    channel读到了一些数据或是接收了一些连接，
    对服务端channel而言，msg是连接
    对客户端channel而言，msg是bytebuf数据
     */
    void channelRead(ChannelHandlerContext ctx, Object msg) throws Exception;
```

```
    /**
    读完之后的回调
     */
    void channelReadComplete(ChannelHandlerContext ctx) throws Exception;

    void userEventTriggered(ChannelHandlerContext ctx, Object evt) throws Exception;

    void channelWritabilityChanged(ChannelHandlerContext ctx) throws Exception;

    /**
    异常捕获的回调
    */
    @Override
    @SuppressWarnings("deprecation")
    void exceptionCaught(ChannelHandlerContext ctx, Throwable cause) throws Exception;
}
```

com.leh.netty.pipeline.InboundHandlerB

```
public class InboundHandlerB extends ChannelInboundHandlerAdapter {
    /**
     * channelHandler收到激活事件后会对收到对象进行打印，并继续传播
     * @param ctx
     * @param msg
     * @throws Exception
     */
    @Override
    public void channelRead(ChannelHandlerContext ctx, Object msg) throws Exception {
        System.out.println("InboundHandlerB: " + msg);
        //通过context调用fireChannelRead 会将事件从当前节点开始传播
        ctx.fireChannelRead(msg);
```

```
    }

    /**
     * 通道被激活的时候拿到对应的 pipeline , 激活一个ChannelRead事件
     * @param ctx
     * @throws Exception
     */
    @Override
    public void channelActive(ChannelHandlerContext ctx) throws Exception {
        //通过channel的Pipeline调用fireChannelRead
        //会将事件从pipeline的headContext节点传播
         ctx.channel().pipeline().fireChannelRead("hello netty");
    }
}
```

io.netty.channel.DefaultChannelPipeline#fireChannelRead

```
//从head开始
public final ChannelPipeline fireChannelRead(Object msg) {
    AbstractChannelHandlerContext.invokeChannelRead(head, msg);
    return this;
}
```

```
static void invokeChannelRead(final AbstractChannelHandlerContext next, Object msg) {
    final Object m = next.pipeline.touch(ObjectUtil.checkNotNull(msg, "msg"), next);
    //此时的next即io.netty.channel.DefaultChannelPipeline.HeadContext
    EventExecutor executor = next.executor();
    if (executor.inEventLoop()) {
        //调用HeadContext的invokeChannelRead方法
        next.invokeChannelRead(m);
    } else {
        executor.execute(new Runnable() {
            @Override
            public void run() {
                next.invokeChannelRead(m);
            }
        });
    }
}
```

```
private void invokeChannelRead(Object msg) {
    if (invokeHandler()) {
        try {
            ((ChannelInboundHandler) handler()).channelRead(this, msg);
        } catch (Throwable t) {
            notifyHandlerException(t);
        }
    } else {
        fireChannelRead(msg);
    }
}
```

io.netty.channel.DefaultChannelPipeline.HeadContext#channelRead

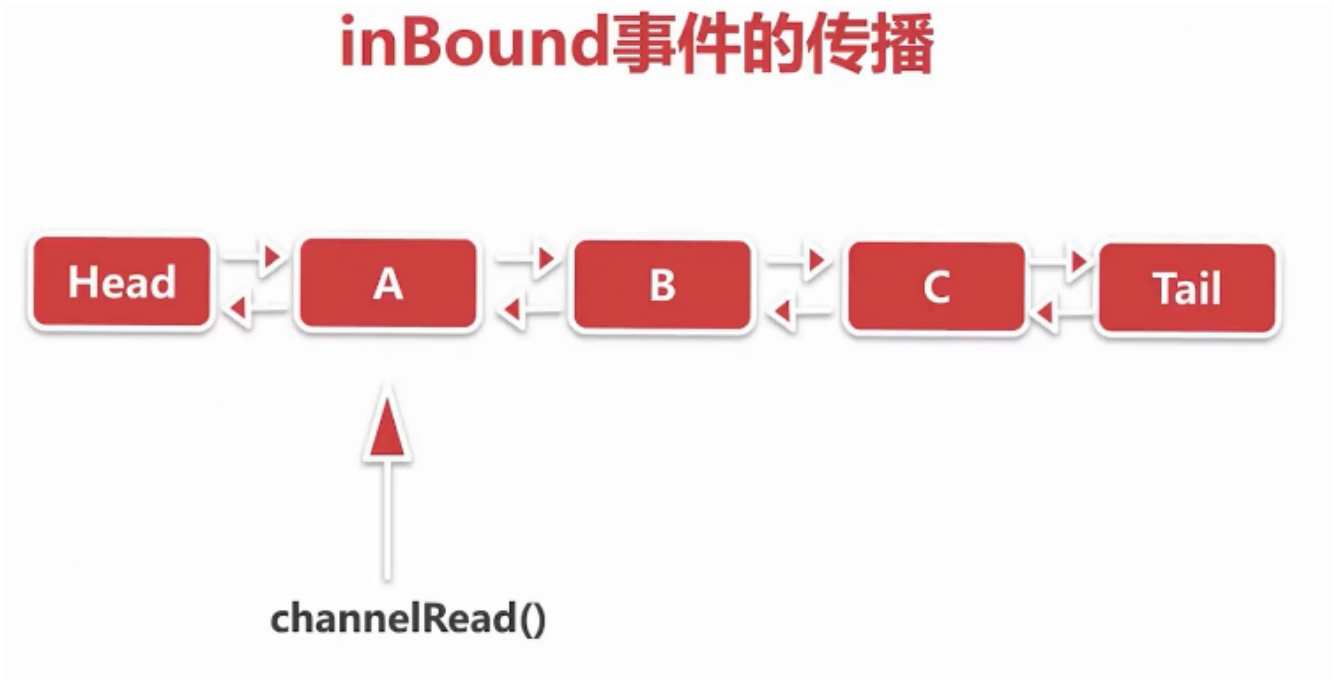
```
@Override
public void channelRead(ChannelHandlerContext ctx, Object msg) throws Exception {
    ctx.fireChannelRead(msg);
}
```

io.netty.channel.AbstractChannelHandlerContext#fireChannelRead

```
public ChannelHandlerContext fireChannelRead(final Object msg) {
    //寻找下一个inboundHandler 找到之后通过invokeChannelRead 继续向下传播
    invokeChannelRead(findContextInbound(), msg);
    return this;
}
```

io.netty.channel.AbstractChannelHandlerContext#findContextInbound

```
private AbstractChannelHandlerContext findContextInbound() {
    AbstractChannelHandlerContext ctx = this;
    do {
        ctx = ctx.next;
    } while (!ctx.inbound);
    //inbound属性在addLast添加handler时候赋值的
    //循环查找，找到inboundhandler即返回
    return ctx;
}
```



此时找到了下一个inboundHandler是com.leh.netty.pipeline.InboundHandlerA

io.netty.channel.AbstractChannelHandlerContext#invokeChannelRead(io.netty.channel.AbstractChannelHandlerContext, java.lang.Object)

```
static void invokeChannelRead(final AbstractChannelHandlerContext next, Object msg) {
    final Object m = next.pipeline.touch(ObjectUtil.checkNotNull(msg, "msg"), next);
    EventExecutor executor = next.executor();
    //此时next是InboundHandlerA
    if (executor.inEventLoop()) {
        next.invokeChannelRead(m);
    } else {
        executor.execute(new Runnable() {
            @Override
            public void run() {
                next.invokeChannelRead(m);
            }
        });
    }
}
```

com.leh.netty.pipeline.InboundHandlerA#channelRead

```
@Override
public void channelRead(ChannelHandlerContext ctx, Object msg) throws Exception {
    System.out.println("InboundHandlerA: " + msg);
    //通过handler直接调用fireChannelRead 会把这个事件从当前节点开始往下传播
    ctx.fireChannelRead(msg);
}
```

同理,接下来继续传播到 B--》C-->Tail

到达TailContext节点，仍然是一个inboundHander

io.netty.channel.DefaultChannelPipeline.TailContext#channelRead

```
public void channelRead(ChannelHandlerContext ctx, Object msg) throws Exception {
    onUnhandledInboundMessage(msg);
}
```

io.netty.channel.DefaultChannelPipeline#onUnhandledInboundMessage

```
//消息传递直到tail节点都未被处理时进入该方法进行打印并释放
protected void onUnhandledInboundMessage(Object msg) {
    try {
        logger.debug(
                "Discarded inbound message {} that reached at the tail of the pipeline. " +
                        "Please check your pipeline configuration.", msg);
    } finally {
        ReferenceCountUtil.release(msg);
    }
}
```

SimpleChannelInBoundHandler处理器应用场景

当channelRead事件传播的时候，如果msg对象是个byteBuf，并且在handler中对byteBuf做了读写处理但没有继续向下传播，那么就传播不到tail节点，就没办法自动释放，这就需要用户自己释放，如果用户代码没有处理释放bytebuf，最终可能导致内存泄漏。

netty帮助我们封装了SimpleChannelInBoundHandler，能够自动释放byteBuf；

SimpleChannelInBoundHandler是如何做到自动释放byteBuf的?

```
public void channelRead(ChannelHandlerContext ctx, Object msg) throws Exception {
    boolean release = true;
    try {
        if (acceptInboundMessage(msg)) {
            @SuppressWarnings("unchecked")
            I imsg = (I) msg;
            channelRead0(ctx, imsg);
        } else {
            release = false;
            ctx.fireChannelRead(msg);
        }
    } finally {
        if (autoRelease && release) {
            //最终由SimpleChannelInBoundHandler自动释放
            ReferenceCountUtil.release(msg);
        }
    }
}

...
 //channelRead0是个抽象方法
 protected abstract void channelRead0(ChannelHandlerContext ctx, I msg) throws Exception;
```

```
public class AuthHandler extends SimpleChannelInboundHandler<ByteBuf> {

    //用户只需要自己去覆盖SimpleChannelInboundHandler的channelRead0方法进行读写，不需要考虑释放
bytebuf
    @Override
    protected void channelRead0方法(ChannelHandlerContext ctx, ByteBuf msg) throws Exception
{
        if (pass(msg)) {
            //校验通过将当前节点删除
            ctx.pipeline().remove(this);
        } else {
            //校验不通过直接关闭连接
            ctx.close();
        }
    }
    @Override
    public void handlerRemoved(ChannelHandlerContext ctx) throws Exception {
        System.out.println("test 回调删除");
    }
    private boolean pass(ByteBuf password) {
        return true;
```

```
    }
}
```

6.7 outBound事件的传播

6.7.1 思考两个问题

- 何为outBound事件及channelOutBoundHandler
- write()事件的传播

  io.netty.channel.ChannelInboundHandler 被动触发的事件

  io.netty.channel.ChannelOutboundHandler 用户主动发起的事件

```
public interface ChannelOutboundHandler extends ChannelHandler {
    /**
     * Called once a bind operation is made.
     */
    void bind(ChannelHandlerContext ctx, SocketAddress localAddress, ChannelPromise
promise) throws Exception;

    /**
     * Called once a connect operation is made.
     */
    void connect(
            ChannelHandlerContext ctx, SocketAddress remoteAddress,
            SocketAddress localAddress, ChannelPromise promise) throws Exception;

    void disconnect(ChannelHandlerContext ctx, ChannelPromise promise) throws
Exception;

    /**
     * Called once a close operation is made.
     */
    void close(ChannelHandlerContext ctx, ChannelPromise promise) throws Exception;

    void deregister(ChannelHandlerContext ctx, ChannelPromise promise) throws
Exception;

    /**
     * Intercepts {@link ChannelHandlerContext#read()}.
     */
    void read(ChannelHandlerContext ctx) throws Exception;

    /**
    * Called once a write operation is made.
     */
    void write(ChannelHandlerContext ctx, Object msg, ChannelPromise promise) throws
Exception;

    /**
     * Called once a flush operation is made.
     */
```

```
    void flush(ChannelHandlerContext ctx) throws Exception;
}
```

```
public final class TestChannelOutboundHandler {

    public static void main(String[] args) {
        // bossGroup 对应 socket编程中 server端 的 线程
        EventLoopGroup bossGroup = new NioEventLoopGroup(1);
        // workGroup 对应 socket编程中 client端 的 线程
        EventLoopGroup workGroup = new NioEventLoopGroup();

        ServerBootstrap bootstrap = new ServerBootstrap();

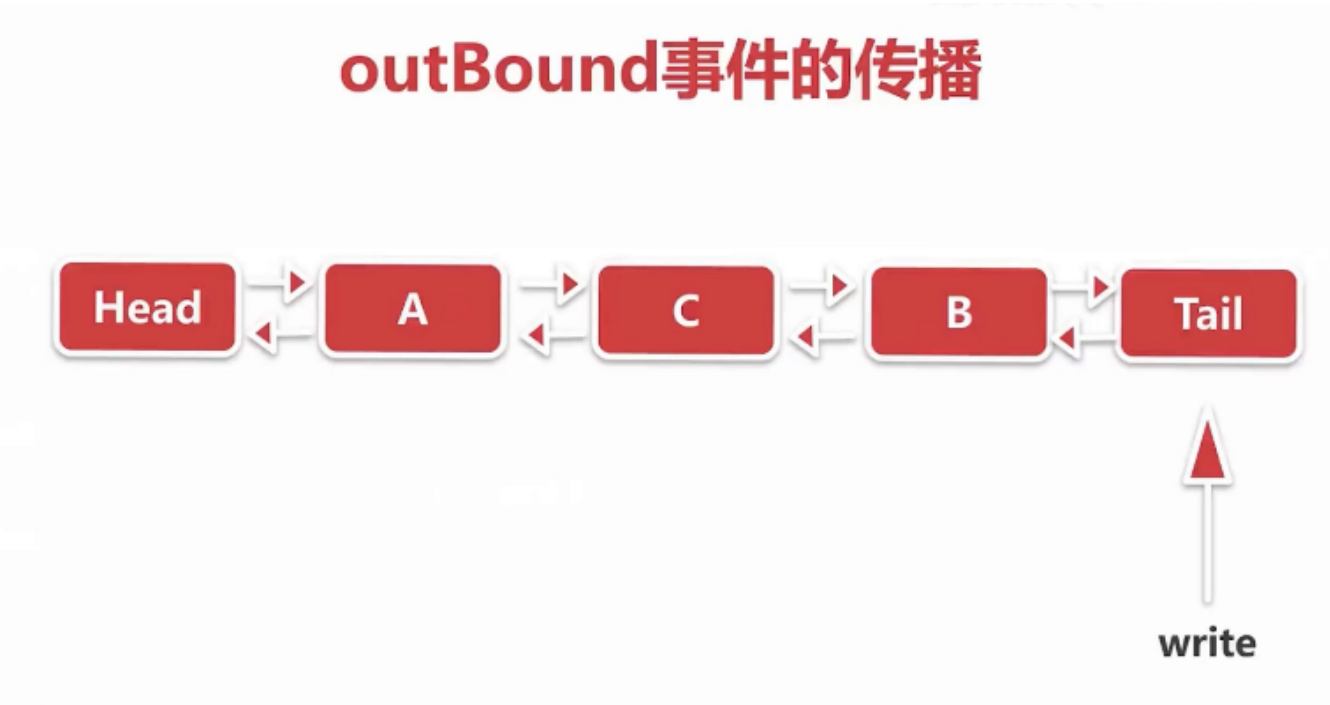
        bootstrap.group(bossGroup, workGroup)
                .channel(NioServerSocketChannel.class)
                .childOption(ChannelOption.TCP_NODELAY, true)
                .childAttr(AttributeKey.newInstance("childAttr"), "childAttrValue")
                .childHandler(new ChannelInitializer<SocketChannel>() {

                    @Override
                    protected void initChannel(SocketChannel ch) throws Exception {
                        ch.pipeline().addLast(new OutboundHandlerA());
                        ch.pipeline().addLast(new OutboundHandlerB());
                        ch.pipeline().addLast(new OutboundHandlerC());
                    }
                });
        try {
            //服务端创建的入口 bind()
            ChannelFuture channelFuture = bootstrap.bind(8888).sync();
            channelFuture.channel().closeFuture().sync();
        } catch (InterruptedException e) {
            e.printStackTrace();
        }
    }
}

output：结论：outboundHandler添加的顺序和在pipeline中传播的顺序是相反的
OutboundHandlerC: hello netty
OutboundHandlerB: hello netty
OutboundHandlerA: hello netty
```

```
public class OutboundHandlerB extends ChannelOutboundHandlerAdapter {
    @Override
    public void write(ChannelHandlerContext ctx, Object msg, ChannelPromise promise) throws
Exception {
        System.out.println("OutboundHandlerB: " + msg);
        //继续向下传播
        ctx.write(msg, promise);
    }
```

```
    /**
     * 做一个定时器的调用
     * 模拟实际项目中读到数据处理完毕后给客户端一个响应
     * @param ctx
     * @throws Exception
     */
    @Override
    public void handlerAdded(ChannelHandlerContext ctx) throws Exception {
        ctx.executor().schedule(() -> {
            //从Tail节点开始传播
            ctx.channel().write("hello netty");
            //从当前节点开始传播
            //ctx.write("hello netty");
        }, 3, TimeUnit.SECONDS);
    }
}
```



6.7.2 源码分析

io.netty.channel.DefaultChannelPipeline#write(java.lang.Object) 委托给pipeline进行读写

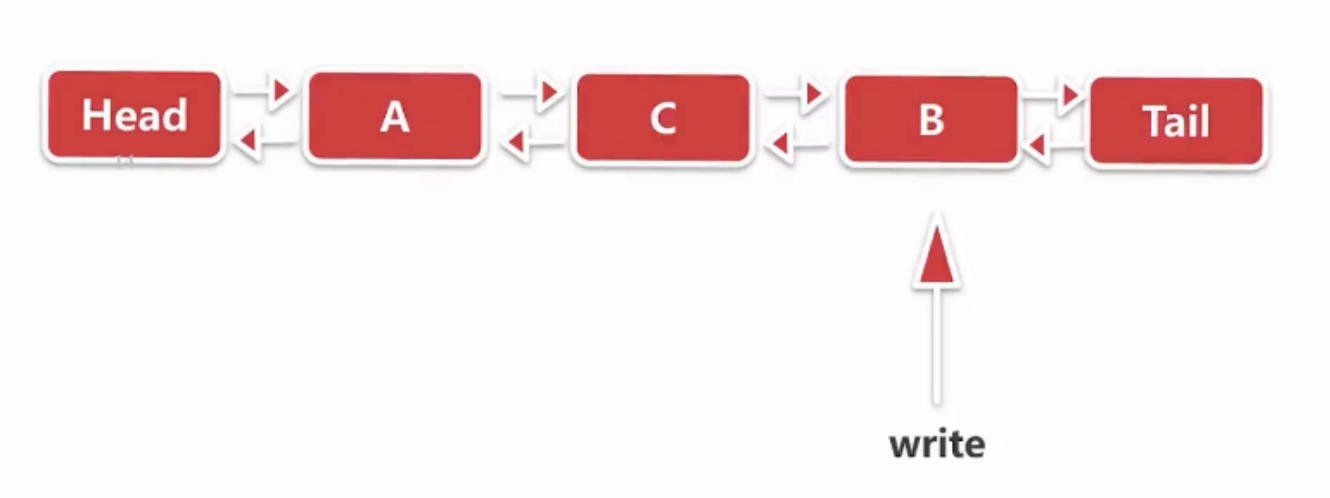
```
//从Tail节点开始往前写
public final ChannelFuture write(Object msg) {
    return tail.write(msg);
}
```

```
public ChannelFuture write(Object msg) {
    //promise是一个回调
    return write(msg, newPromise());
}
```

```
private void write(Object msg, boolean flush, ChannelPromise promise) {
    //寻找outbound节点
    AbstractChannelHandlerContext next = findContextOutbound();
    final Object m = pipeline.touch(msg, next);
    EventExecutor executor = next.executor();
    if (executor.inEventLoop()) {
        if (flush) {
            next.invokeWriteAndFlush(m, promise);
        } else {
            //找到B节点后调用
            next.invokeWrite(m, promise);
        }
    } else {
        AbstractWriteTask task;
        if (flush) {
            task = WriteAndFlushTask.newInstance(next, m, promise);
        }  else {
            task = WriteTask.newInstance(next, m, promise);
        }
        safeExecute(executor, task, promise, m);
    }
}
```

io.netty.channel.AbstractChannelHandlerContext#findContextOutbound

```
private AbstractChannelHandlerContext findContextOutbound() {
    AbstractChannelHandlerContext ctx = this;
    do {
        ctx = ctx.prev;
    } while (!ctx.outbound);
    return ctx;
}
```



io.netty.channel.AbstractChannelHandlerContext#invokeWrite0

```
private void invokeWrite0(Object msg, ChannelPromise promise) {
    try {
        ((ChannelOutboundHandler) handler()).write(this, msg, promise);
    } catch (Throwable t) {
        notifyOutboundHandlerException(t, promise);
    }
}
```

com.leh.netty.pipeline.OutboundHandlerB#write

```
public void write(ChannelHandlerContext ctx, Object msg, ChannelPromise promise) throws
Exception {
    System.out.println("OutboundHandlerB: " + msg);
    //继续向下传播
    ctx.write(msg, promise);
}
```

直到到达HeadContext节点

io.netty.channel.DefaultChannelPipeline.HeadContext#write

```
@Override
public void write(ChannelHandlerContext ctx, Object msg, ChannelPromise promise) throws
Exception {
    //最终调用unsafe的write方法，不再往下传播
    unsafe.write(msg, promise);
}
```

6.8 异常的传播

- inbound事件传播的顺序和在应用程序中添加inboundHandler的顺序正相关
- outbound事件传播的顺序和在应用程序中添加outboundHandler的顺序逆相关
- 那么异常呢?

模拟异常传播

`telnet 127.0.0.1 8888` 模拟客户端连接

`send ayt` 模拟发送消息

```
public final class TestExceptionSpread {

    public static void main(String[] args) {
        // bossGroup 对应 socket编程中 server端 的 线程
        EventLoopGroup bossGroup = new NioEventLoopGroup(1);
        // workGroup 对应 socket编程中 client端 的 线程
        EventLoopGroup workGroup = new NioEventLoopGroup();

        ServerBootstrap bootstrap = new ServerBootstrap();
```

```
        bootstrap.group(bossGroup, workGroup)
                .channel(NioServerSocketChannel.class)
                .childOption(ChannelOption.TCP_NODELAY, true)
                .childAttr(AttributeKey.newInstance("childAttr"), "childAttrValue")
                .childHandler(new ChannelInitializer<SocketChannel>() {
                    @Override
                    protected void initChannel(SocketChannel ch) throws Exception {
                        ch.pipeline().addLast(new ExceptionInboundHandlerA());
                        ch.pipeline().addLast(new ExceptionInboundHandlerB());
                        ch.pipeline().addLast(new ExceptionInboundHandlerC());
                        ch.pipeline().addLast(new ExceptionOutboundHandlerA());
                        ch.pipeline().addLast(new ExceptionOutboundHandlerB());
                        ch.pipeline().addLast(new ExceptionOutboundHandlerC());
                    }
                });
        try {
            //服务端创建的入口 bind()
            ChannelFuture channelFuture = bootstrap.bind(8888).sync();
            channelFuture.channel().closeFuture().sync();
        } catch (InterruptedException e) {
            e.printStackTrace();
        }
    }
}
output:
ExceptionInboundHandlerB.exceptionCaught
ExceptionInboundHandlerC.exceptionCaught
ExceptionOutboundHandlerA.exceptionCaught
ExceptionOutboundHandlerB.exceptionCaught
ExceptionOutboundHandlerC.exceptionCaught
```

模拟异常

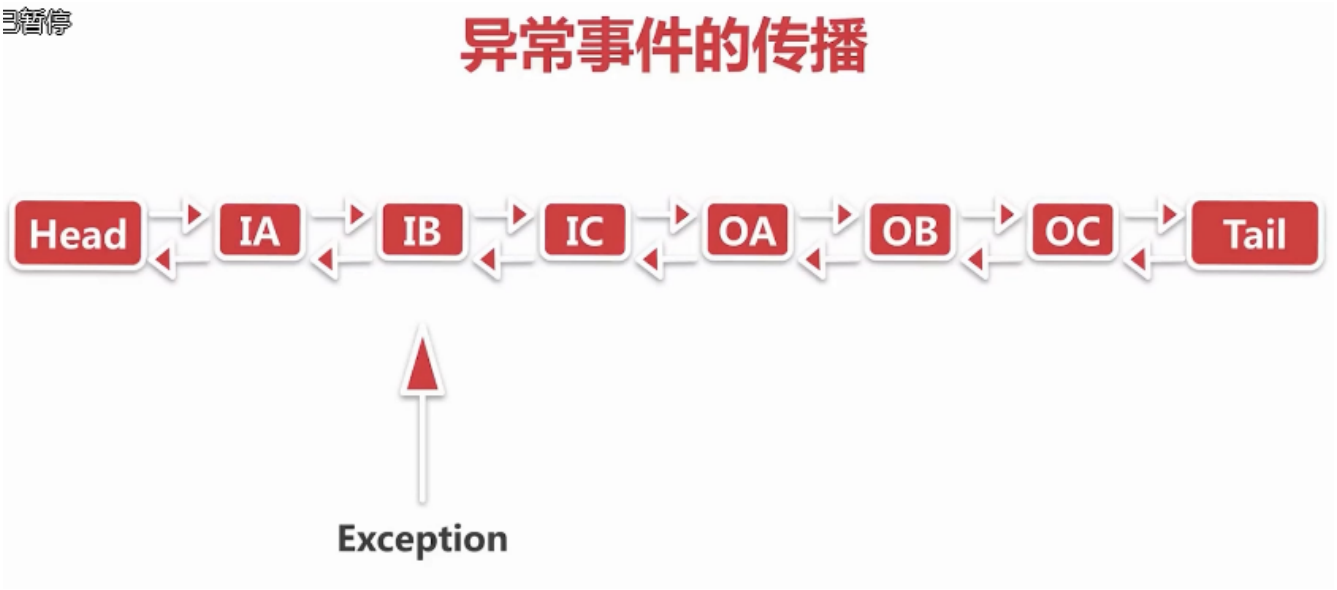
```
public class ExceptionInboundHandlerB extends ChannelInboundHandlerAdapter {

    //抛出异常
    @Override
    public void channelRead(ChannelHandlerContext ctx, Object msg) throws Exception {
        throw new BusinessException("exception from ExceptionInboundHandlerB");
    }

    //抛出异常回调
    @Override
    public void exceptionCaught(ChannelHandlerContext ctx, Throwable cause) throws Exception
{
        System.out.println("ExceptionInboundHandlerB.exceptionCaught");
        //异常向下传播
        ctx.fireExceptionCaught(cause);
    }
}
```

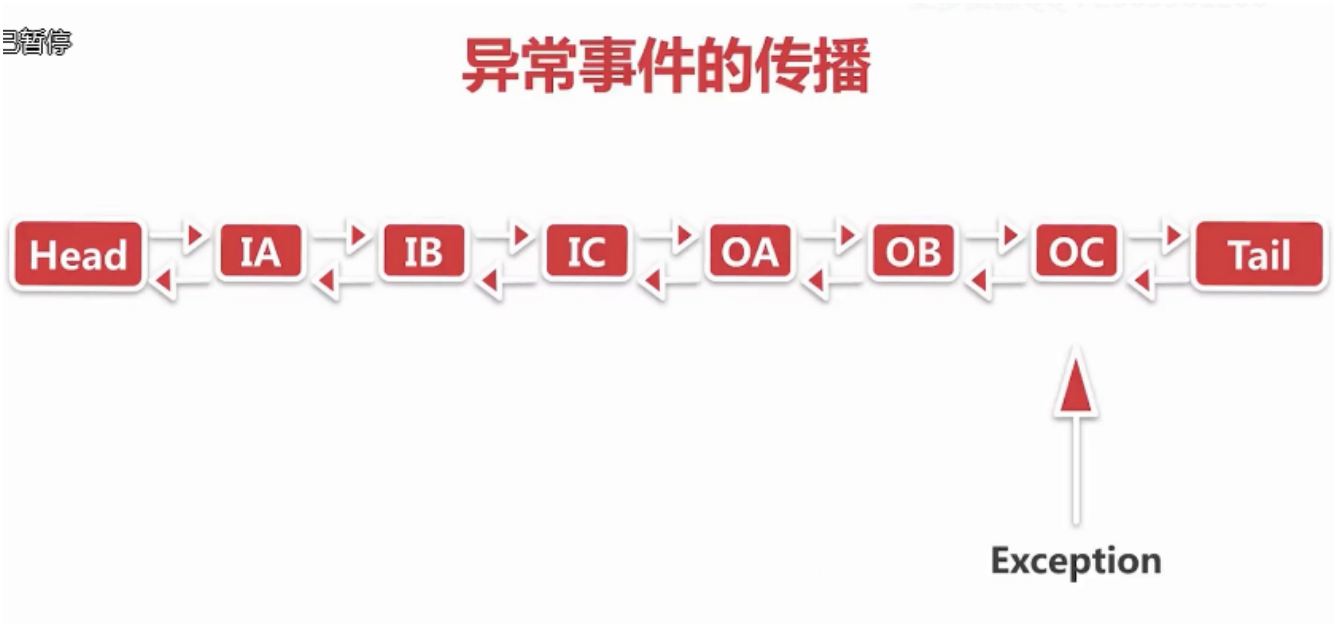
6.8.1 netty 异常的触发链

- netty异常的传播与channelHandler的添加顺序正相关，当其中某个channelHandler读写数据发生异常，就会把异常从当前节点开始逐个向下传播，如果传播到最后一个节点没有异常处理器的话，最终到Tail节点，tail节点默认会给一个告警，并进行异常信息的打印。



io.netty.channel.AbstractChannelHandlerContext#fireExceptionCaught

```
//向下传播直接拿到当前的节点的next节点
public ChannelHandlerContext fireExceptionCaught(final Throwable cause) {
    invokeExceptionCaught(next, cause);
    return this;
}
```



直到传播到Tail节点--》相当于哨兵

io.netty.channel.DefaultChannelPipeline.TailContext#exceptionCaught

```
public void exceptionCaught(ChannelHandlerContext ctx, Throwable cause) throws Exception {
    onUnhandledInboundException(cause);
}
```

```
io.netty.channel.DefaultChannelPipeline#onUnhandledInboundException
protected void onUnhandledInboundException(Throwable cause) {
    try {
        logger.warn(
                "An exceptionCaught() event was fired, and it reached at the tail of the
pipeline. " +
                        "It usually means the last handler in the pipeline did not handle
the exception.",
                cause);
    } finally {
        ReferenceCountUtil.release(cause);
    }
}
```

6.8.2 netty 实际项目中异常处理最佳实践

在每一条channelHandler链的最后添加终极的异常处理器，确保所有的异常若中途没有被处理，

都会落到此处理器，并且可以针对不同的异常类型分别处理

```
public class ExceptionCaughtHandler extends ChannelInboundHandlerAdapter {
    @Override
    public void exceptionCaught(ChannelHandlerContext ctx, Throwable cause) throws Exception
{
        //根据异常的类型进行处理
        if (cause instanceof BusinessException) {
            System.out.println("BusinessException");
        }
    }
}
```

```
public final class TestExceptionSpread {

    public static void main(String[] args) {

        EventLoopGroup bossGroup = new NioEventLoopGroup(1);

        EventLoopGroup workGroup = new NioEventLoopGroup();

        ServerBootstrap bootstrap = new ServerBootstrap();

        bootstrap.group(bossGroup, workGroup)
                .channel(NioServerSocketChannel.class)
                .childOption(ChannelOption.TCP_NODELAY, true)
                .childAttr(AttributeKey.newInstance("childAttr"), "childAttrValue")
                .childHandler(new ChannelInitializer<SocketChannel>() {
```

```
                    @Override
                    protected void initChannel(SocketChannel ch) throws Exception {
                        ch.pipeline().addLast(new ExceptionInboundHandlerA());
                        ch.pipeline().addLast(new ExceptionInboundHandlerB());
                        ch.pipeline().addLast(new ExceptionInboundHandlerC());
                        ch.pipeline().addLast(new ExceptionOutboundHandlerA());
                        ch.pipeline().addLast(new ExceptionOutboundHandlerB());
                        ch.pipeline().addLast(new ExceptionOutboundHandlerC());
                        //添加终极异常处理器
                        ch.pipeline().addLast(new ExceptionCaughtHandler());
                    }
                });
        try {
            //服务端创建的入口 bind()
            ChannelFuture channelFuture = bootstrap.bind(8888).sync();
            channelFuture.channel().closeFuture().sync();
        } catch (InterruptedException e) {
            e.printStackTrace();
        }
    }
}
//output:
ExceptionInboundHandlerB.exceptionCaught
ExceptionInboundHandlerC.exceptionCaught
ExceptionOutboundHandlerA.exceptionCaught
ExceptionOutboundHandlerB.exceptionCaught
ExceptionOutboundHandlerC.exceptionCaught
BusinessException
```

七、netty - byteBuf

本章是netty `内存分配` 相关的内容, byteBuf 是直接与底层i/o打交道的一层抽象。

7.1 思考问题

- 内存的类别有哪些
    - 堆内内存 和堆外内存
- 如何减少多线程内存分配之间的竞争
- 不同大小的内存是如何进行分配的

7.2 本章主要内容

- 内存与内存管理器的抽象
- 不同规格大小和不同类别的内存的分配策略
- 内存的回收过程

7.3 byteBuf的结构以及重要API

7.3.1 byteBuf结构

```
* <pre>
*      +-------------------+------------------+------------------+
*      | discardable bytes |  readable bytes  |  writable bytes  |
*      |                   |     (CONTENT)    |                  |
*      +-------------------+------------------+------------------+
*      |                   |                  |                  |
*      0      <=      readerIndex   <=   writerIndex    <=    capacity  (<= MaxCapacity)
* </pre>
```

readerIndex :若读操作，从当前指针开始读数据

writerIndex：若写操作，从当前指针开始写

0 - readerIndex 无效的数据

readerIndex - writerIndex 可读的数据

writerIndex - capacity 表明这段空闲的，可以进行写

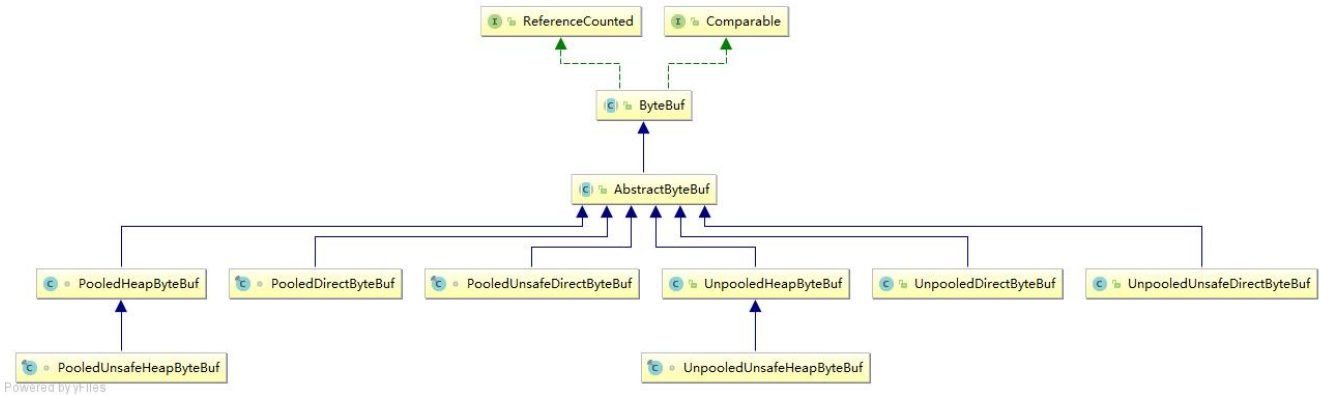
capacity - MaxCapacity 当写的空间不足，netty会提前将`writable bytes`部分会进行扩容，MaxCapacity 表示最大能扩充的空间，若仍超过此空间，则会拒绝

7.3.2 read， write ， set方法

7.3.3 mark 和reset方法

7.4 byteBuf的分类

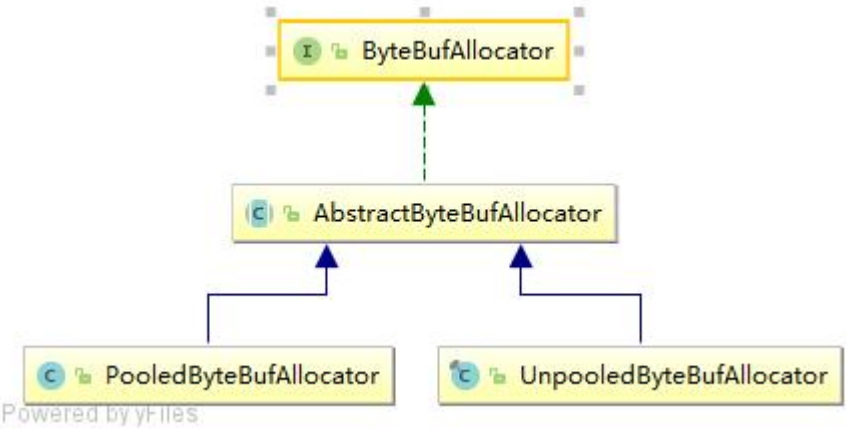
- pooled 和 unpooled
    - pooled 从池子中取一段预先分配好的内存
    - unpooled 直接调用现有的API去分配一块内存
- unsafe 和 非unsafe
    - unsafe 依赖jdk底层的unsafe对象
    - 非unsafe 不依赖jdk底层的unsafe对象
- Heap 和 Direct



```
/**
A skeletal implementation of a buffer. 实现基本骨架
*/
io.netty.buffer.AbstractByteBuf
public abstract class AbstractByteBuf extends ByteBuf {
    ...
    int readerIndex;
    int writerIndex;
    private int markedReaderIndex;
    private int markedWriterIndex;
    private int maxCapacity;
    ...
}
```

7.5 内存分配器 ByteBufAllocator分析

思考：ByteBufAllocator是如何对上节中6中类型的byteBuf是如何分配的



最顶层抽象 io.netty.buffer.ByteBufAllocator 负责分配所有类型的内存

- ByteBufAllocator
- AbstractByteBufAllocator
    - 暴露两个方法交给具体子类实现

```
/** 堆上内存
 * Create a heap {@link ByteBuf} with the given initialCapacity and
maxCapacity.
 */
protected abstract ByteBuf newHeapBuffer(int initialCapacity, int
maxCapacity);

/** 堆外内存
 * Create a direct {@link ByteBuf} with the given initialCapacity and
maxCapacity.
 */
protected abstract ByteBuf newDirectBuffer(int initialCapacity, int
maxCapacity);
```

- ByteBufAllocator 两大子类

- PooledByteBufAllocator
- UnpooledByteBufAllocator

7.6 UnpooledByteBufAllocator 分析

- heap内存的分配

  io.netty.buffer.UnpooledByteBufAllocator#newHeapBuffer

```
protected ByteBuf newHeapBuffer(int initialCapacity, int maxCapacity) {
    // netty自己判断是否有unsafe对象
    return PlatformDependent.hasUnsafe() ? new UnpooledUnsafeHeapByteBuf(this,
initialCapacity, maxCapacity)
            : new UnpooledHeapByteBuf(this, initialCapacity, maxCapacity);
}
```

- direct内存的分配

```
protected ByteBuf newDirectBuffer(int initialCapacity, int maxCapacity) {
    ByteBuf buf = PlatformDependent.hasUnsafe() ?
            UnsafeByteBufUtil.newUnsafeDirectByteBuf(this, initialCapacity,
maxCapacity) :
            new UnpooledDirectByteBuf(this, initialCapacity, maxCapacity);

    return disableLeakDetector ? buf : toLeakAwareBuffer(buf);
}
```

```
io.netty.buffer.UnpooledUnsafeDirectByteBuf#setByteBuffer
final void setByteBuffer(ByteBuffer buffer, boolean tryFree) {
    if (tryFree) {
        ByteBuffer oldBuffer = this.buffer;
        if (oldBuffer != null) {
            if (doNotFree) {
                doNotFree = false;
            } else {
                freeDirect(oldBuffer);
            }
        }
    }
    this.buffer = buffer;
    //获取buffer内存地址并保存
    memoryAddress = PlatformDependent.directBufferAddress(buffer);
    tmpNioBuf = null;
    capacity = buffer.remaining();
}
```

```
io.netty.util.internal.PlatformDependent#directBufferAddress
public static long directBufferAddress(ByteBuffer buffer) {
    return PlatformDependent0.directBufferAddress(buffer);
}
```

```
static long directBufferAddress(ByteBuffer buffer) {
    return getLong(buffer, ADDRESS_FIELD_OFFSET);
}
```

io.netty.util.internal.PlatformDependent0#getLong(java.lang.Object, long)

```
private static long getLong(Object object, long fieldOffset) {
    return UNSAFE.getLong(object, fieldOffset);
}
```

取数据

io.netty.buffer.UnpooledUnsafeDirectByteBuf#_getByte

```
protected byte _getByte(int index) {
    return UnsafeByteBufUtil.getByte(addr(index));
}
```

```
io.netty.buffer.UnsafeByteBufUtil#getByte(long)
static byte getByte(long address) {
    return PlatformDependent.getByte(address);
}
```

```
io.netty.util.internal.PlatformDependent0#getByte(long)
static byte getByte(long address) {
    return UNSAFE.getByte(address);
}
```

io.netty.buffer.UnpooledDirectByteBuf#_getByte

```
protected byte _getByte(int index) {
    //调用jdk的ByteBuffer的API
    return buffer.get(index);
}
```

分析：unsafe和非unsafe的认识：

非unsafe 最终会通过一个内存地址 + 偏移量的方式去拿到对应的数据；

而非unsafe会通过 数组 + 下标 调用jdk底层的ByteBuffer的api去拿数据

一般而言通过unsafe取数据要快一点。

7.7 PooledByteBufAllocator 分析

- 拿到线程局部缓存PoolThreadCache （多线程调用newHeapBuffer时拿到当前线程的cache）
- 在线程局部缓存的Area上进行内存分配

以 `io.netty.buffer.PooledByteBufAllocator#newHeapBuffer` 为例：

```
final class PoolThreadLocalCache extends FastThreadLocal<PoolThreadCache> {

    @Override
    protected synchronized PoolThreadCache initialValue() {
        final PoolArena<byte[]> heapArena = leastUsedArena(heapArenas);
        final PoolArena<ByteBuffer> directArena = leastUsedArena(directArenas);

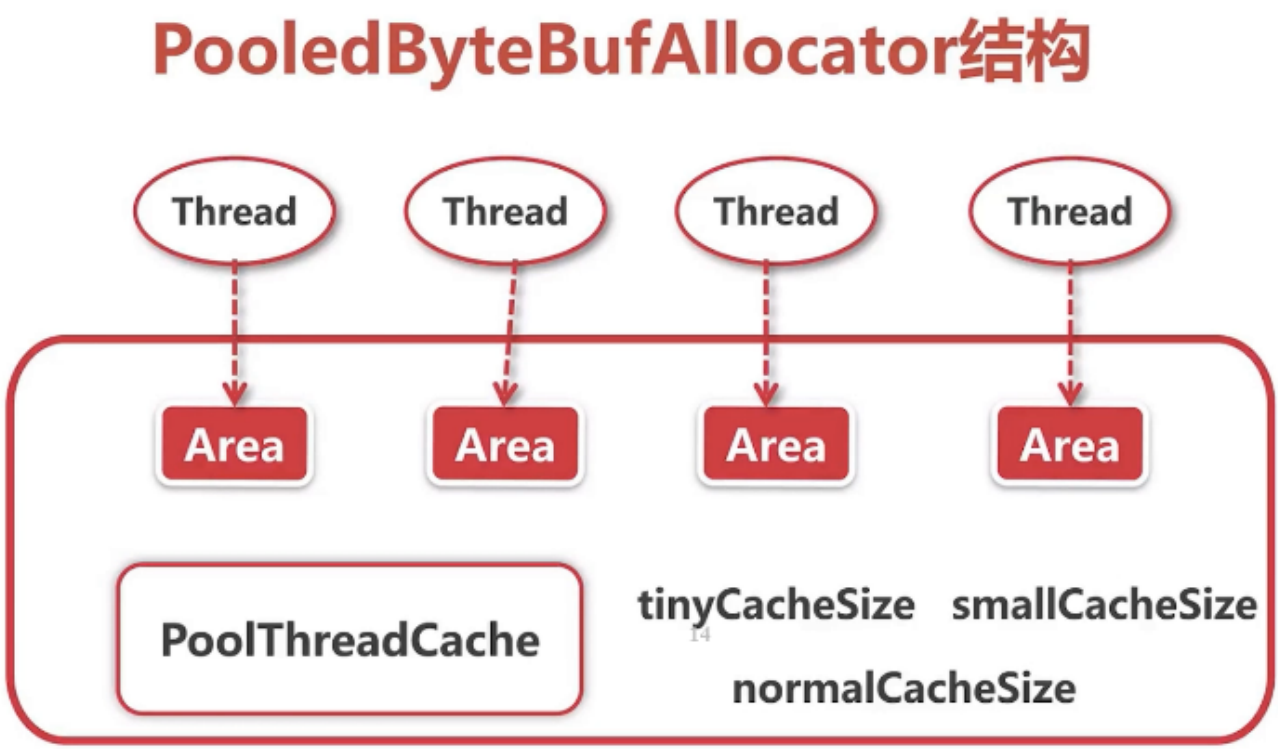
        return new PoolThreadCache(
                heapArena, directArena, tinyCacheSize, smallCacheSize, normalCacheSize,
                DEFAULT_MAX_CACHED_BUFFER_CAPACITY, DEFAULT_CACHE_TRIM_INTERVAL);
    }
    ......
}
```

```
private final PoolThreadLocalCache threadCache;

...
protected ByteBuf newHeapBuffer(int initialCapacity, int maxCapacity) {
    PoolThreadCache cache = threadCache.get();
    PoolArena<byte[]> heapArena = cache.heapArena;

    ByteBuf buf;
    if (heapArena != null) {
        buf = heapArena.allocate(cache, initialCapacity, maxCapacity);
    } else {
        buf = new UnpooledHeapByteBuf(this, initialCapacity, maxCapacity);
    }

    return toLeakAwareBuffer(buf);
}
```



7.8 directArena分配direct内存的流程

- 从对象池里面拿到PooledByteBuf进行复用
    - PoolThreadCache 是每一个线程都会维护的一个对象
- 从缓存上j进行内存分配
- 从内存堆里面进行内存分配

以`io.netty.buffer.PooledByteBufAllocator#newDirectBuffer`为例:

```
protected ByteBuf newDirectBuffer(int initialCapacity, int maxCapacity) {
    PoolThreadCache cache = threadCache.get();
    PoolArena<ByteBuffer> directArena = cache.directArena;

    ByteBuf buf;
    if (directArena != null) {
        buf = directArena.allocate(cache, initialCapacity, maxCapacity);
    } else {
        if (PlatformDependent.hasUnsafe()) {
            buf = UnsafeByteBufUtil.newUnsafeDirectByteBuf(this, initialCapacity,
maxCapacity);
        } else {
            buf = new UnpooledDirectByteBuf(this, initialCapacity, maxCapacity);
        }
    }
    return toLeakAwareBuffer(buf);
}
```

io.netty.buffer.PoolArena#allocate(io.netty.buffer.PoolThreadCache, int, int)

```
PooledByteBuf<T> allocate(PoolThreadCache cache, int reqCapacity, int maxCapacity) {
    //第一步 拿到byteBuf
    PooledByteBuf<T> buf = newByteBuf(maxCapacity);
    //第二步 进行内存分配 （先在缓存上进行内存分配，若未命中缓存，则进行实际的内存分配）
    allocate(cache, buf, reqCapacity);
    return buf;
}
```

io.netty.buffer.PoolArena.DirectArena#newByteBuf

```
protected PooledByteBuf<ByteBuffer> newByteBuf(int maxCapacity) {
    if (HAS_UNSAFE) {
        return PooledUnsafeDirectByteBuf.newInstance(maxCapacity);
    } else {
        return PooledDirectByteBuf.newInstance(maxCapacity);
    }
}
```

io.netty.buffer.PooledUnsafeDirectByteBuf#newInstance

```
private static final Recycler<PooledUnsafeDirectByteBuf> RECYCLER = new
Recycler<PooledUnsafeDirectByteBuf>() {
        @Override
        protected PooledUnsafeDirectByteBuf newObject(Handle<PooledUnsafeDirectByteBuf>
handle) {
            //handle负责byteBuf对象的回收
            return new PooledUnsafeDirectByteBuf(handle, 0);
        }
    };

static PooledUnsafeDirectByteBuf newInstance(int maxCapacity) {
    //带有回收特性的对象池
    PooledUnsafeDirectByteBuf buf = RECYCLER.get();
    //复用byteBuf对象
    buf.reuse(maxCapacity);
    return buf;
}
```

io.netty.buffer.PooledByteBuf#reuse

```
final void reuse(int maxCapacity) {
    maxCapacity(maxCapacity);
    setRefCnt(1);
    setIndex0(0, 0);
    discardMarks();
}
```

7.9 内存规格的介绍

不同大小内存的分配逻辑是不一样的。

为什么把16M作为分界点？

16M对应Chunk，所有的内存申请都是通过以Chunk为单位向操作系统进行申请的，后续所有的内存分配都是在Chunk里面做对应的操作。

例如 要分配一个1M的内存，首先申请一个16M的Chunk --》在16M里面取出一段内存作为1M --》把1M对应的连续内存扔到ByteBuf里面。

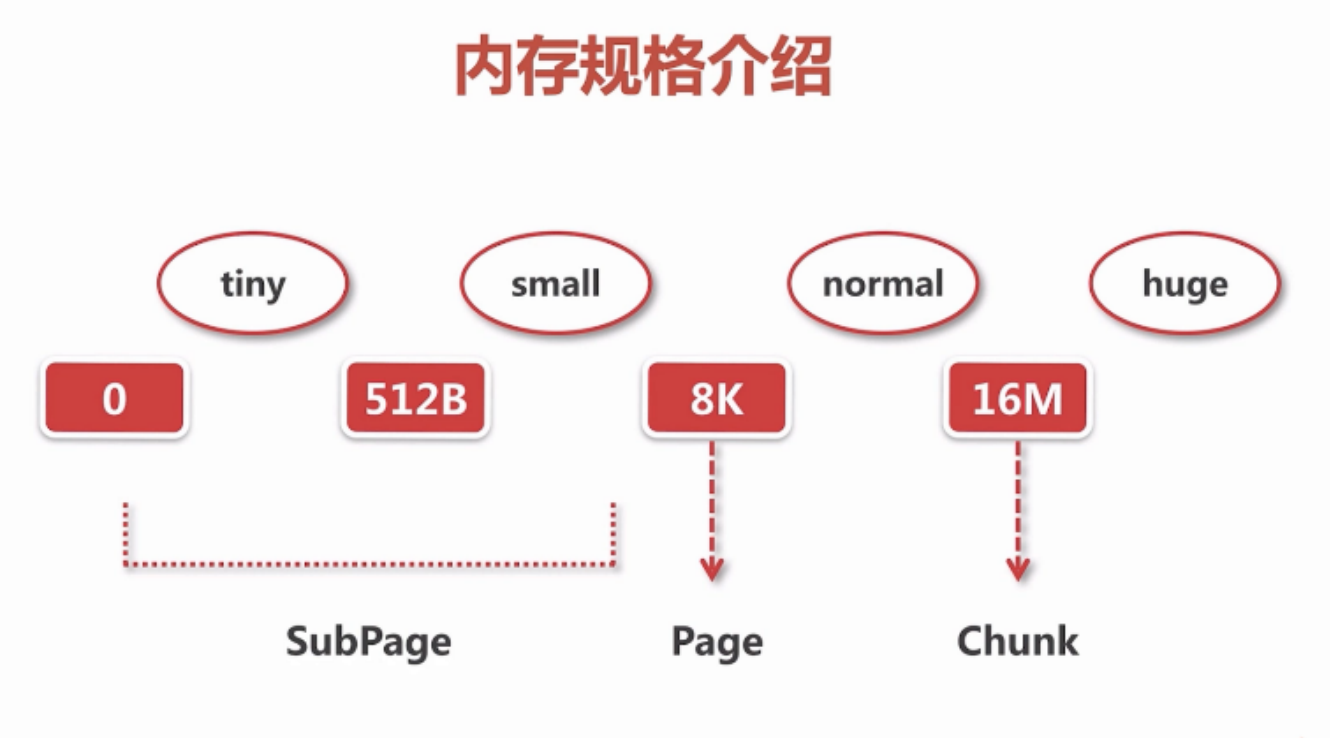
为什么把8K作为分界点？

16M可能有点大，把16M的Chunk按page的方式切分，16M/8k = 2^11个page=2048 1page = 8K

这样想要分配16k内存的时候，只需要找到两个连续的page即可，这样的分配更高效

比如要申请16个字节，如果以page进行分配，可能会很浪费，netty按照内存大小的规格把8K继续进行切分。

若要分配512B，将8k分成 8k/512个片段，每次找到一个空闲的片段进行分配即可。



7.10 缓存数据结构

netty中与缓存相关的数据结构: **MemoryRegionCache**

MemoryRegionCache由3部分组成:

- queue
    - 每一个元素是个实体entry
        - chunk 代表分配单位
        - handler 指向一段唯一连续的内存
- sizeClass netty中的内存规格
    - tiny
    - small
    - normal
- size

io.netty.buffer.PoolThreadCache

io.netty.buffer.PoolArena.SizeClass

```
enum SizeClass {
        Tiny,
        Small,
        Normal
    }
```

io.netty.buffer.PoolThreadCache.MemoryRegionCache.Entry

```
static final class Entry<T> {
    final Handle<Entry<?>> recyclerHandle;
    PoolChunk<T> chunk;
    long handle = -1;

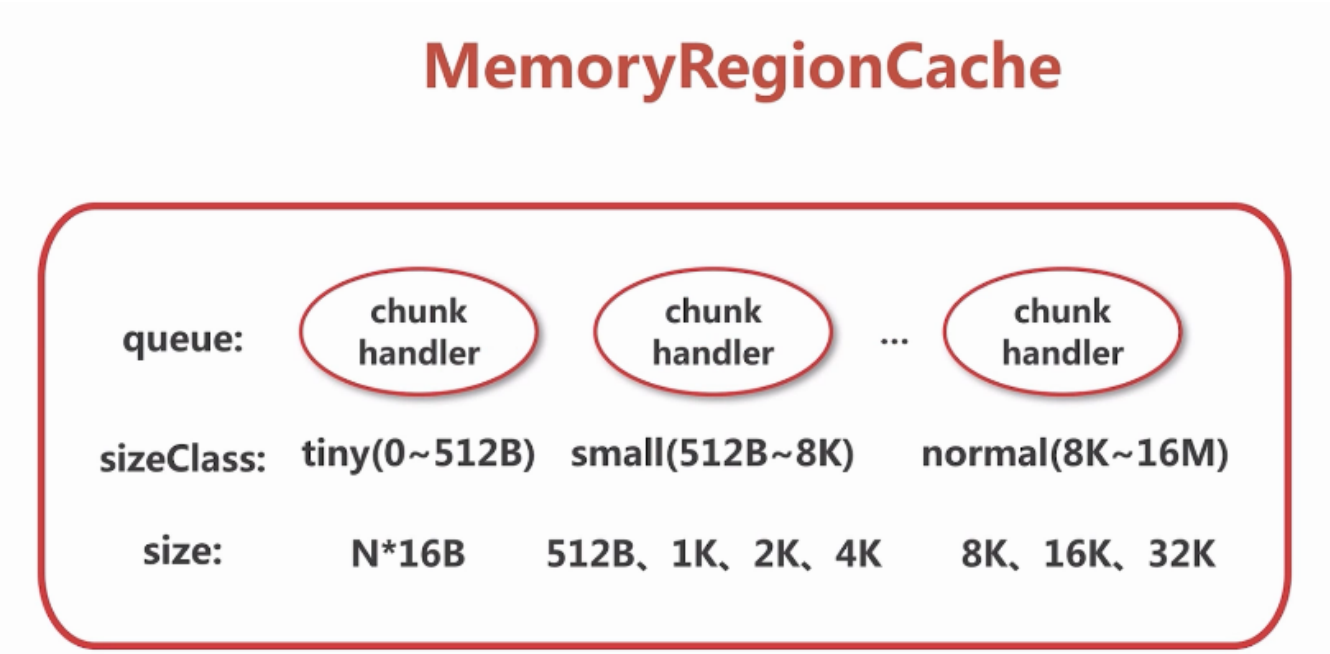
    Entry(Handle<Entry<?>> recyclerHandle) {
        this.recyclerHandle = recyclerHandle;
    }

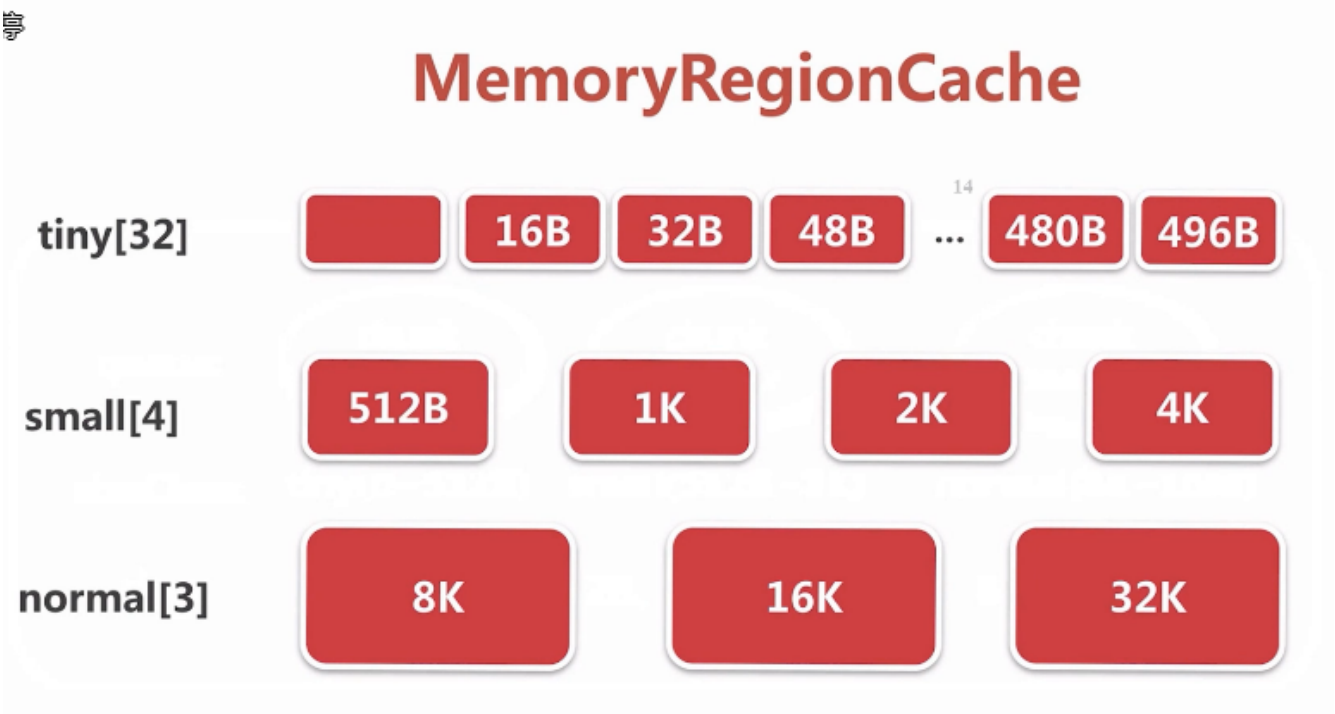
    void recycle() {
        chunk = null;
        handle = -1;
        recyclerHandle.recycle(this);
    }
}
```

io.netty.buffer.PoolThreadCache.MemoryRegionCache

```
private abstract static class MemoryRegionCache<T> {
    private final int size;
    private final Queue<Entry<T>> queue;
    private final SizeClass sizeClass;
    private int allocations;

    MemoryRegionCache(int size, SizeClass sizeClass) {
        this.size = MathUtil.safeFindNextPositivePowerOfTwo(size);
        queue = PlatformDependent.newFixedMpscQueue(this.size);
        this.sizeClass = sizeClass;
    }
    ......
}
```





io.netty.buffer.PoolArena#numTinySubpagePools

```
//右移4位 相当于 除以 16
static final int numTinySubpagePools = 512 >>> 4;//32
```

io.netty.buffer.PoolThreadCache#PoolThreadCache

```
final class PoolThreadCache {

    private static final InternalLogger logger =
InternalLoggerFactory.getInstance(PoolThreadCache.class);

    //Arena 竞技场 直接开辟一块内存
    final PoolArena<byte[]> heapArena;
    final PoolArena<ByteBuffer> directArena;

    // Hold the caches for the different size classes, which are tiny, small and normal.
    //缓存一块连续内存
    private final MemoryRegionCache<byte[]>[] tinySubPageHeapCaches;
    private final MemoryRegionCache<byte[]>[] smallSubPageHeapCaches;
    private final MemoryRegionCache<ByteBuffer>[] tinySubPageDirectCaches;
    private final MemoryRegionCache<ByteBuffer>[] smallSubPageDirectCaches;
    private final MemoryRegionCache<byte[]>[] normalHeapCaches;
    private final MemoryRegionCache<ByteBuffer>[] normalDirectCaches;
    ...
}
```

```
tinySubPageDirectCaches = createSubPageCaches(
        tinyCacheSize, PoolArena.numTinySubpagePools, SizeClass.Tiny);
```

小结：每一个线程中维护一个PoolThreadCache，PoolThreadCache会维护三种内存规格大小的cache，每种规格的cache又进行细分，其数组中的每一个元素都维持缓存队列，即MemoryRegionCache。

7.11 命中缓存的分配流程

- 找到对应size的MemoryRegionCache
- 从queue中弹出一个entry给ByteBuf初始化
- 将弹出的entry扔到对象池中进行复用
    - 通过Recycle回收，减少GC，减少对象重复的创建与销毁

内存分配的入口：

io.netty.buffer.PoolArena#allocate(io.netty.buffer.PoolThreadCache, io.netty.buffer.PooledByteBuf, int)

```
// capacity < pageSize
    boolean isTinyOrSmall(int normCapacity) {
        return (normCapacity & subpageOverflowMask) == 0;
    }

    // normCapacity < 512
    static boolean isTiny(int normCapacity) {
        return (normCapacity & 0xFFFFFE00) == 0;
    }

    private void allocate(PoolThreadCache cache, PooledByteBuf<T> buf, final int
reqCapacity) {
        final int normCapacity = normalizeCapacity(reqCapacity);
        if (isTinyOrSmall(normCapacity)) { // capacity < pageSize
            int tableIdx;
            PoolSubpage<T>[] table;
            boolean tiny = isTiny(normCapacity);
            if (tiny) { // < 512
                //第一种
                if (cache.allocateTiny(this, buf, reqCapacity, normCapacity)) {
                    // was able to allocate out of the cache so move on
                    return;
                }
                tableIdx = tinyIdx(normCapacity);
                table = tinySubpagePools;
            } else {
                //第二种
                if (cache.allocateSmall(this, buf, reqCapacity, normCapacity)) {
                    // was able to allocate out of the cache so move on
                    return;
                }
                tableIdx = smallIdx(normCapacity);
                table = smallSubpagePools;
            }

            final PoolSubpage<T> head = table[tableIdx];

            synchronized (head) {
                final PoolSubpage<T> s = head.next;
```

```
                if (s != head) {
                    assert s.doNotDestroy && s.elemSize == normCapacity;
                    long handle = s.allocate();
                    assert handle >= 0;
                    s.chunk.initBufWithSubpage(buf, handle, reqCapacity);

                    if (tiny) {
                        allocationsTiny.increment();
                    } else {
                        allocationsSmall.increment();
                    }
                    return;
                }
            }
            allocateNormal(buf, reqCapacity, normCapacity);
            return;
        }
        if (normCapacity <= chunkSize) {
            //第三种
            if (cache.allocateNormal(this, buf, reqCapacity, normCapacity)) {
                // was able to allocate out of the cache so move on
                return;
            }
            allocateNormal(buf, reqCapacity, normCapacity);
        } else {
            // Huge allocations are never served via the cache so just call allocateHuge
            allocateHuge(buf, reqCapacity);
        }
    }
```

io.netty.buffer.PoolThreadCache.MemoryRegionCache#allocate

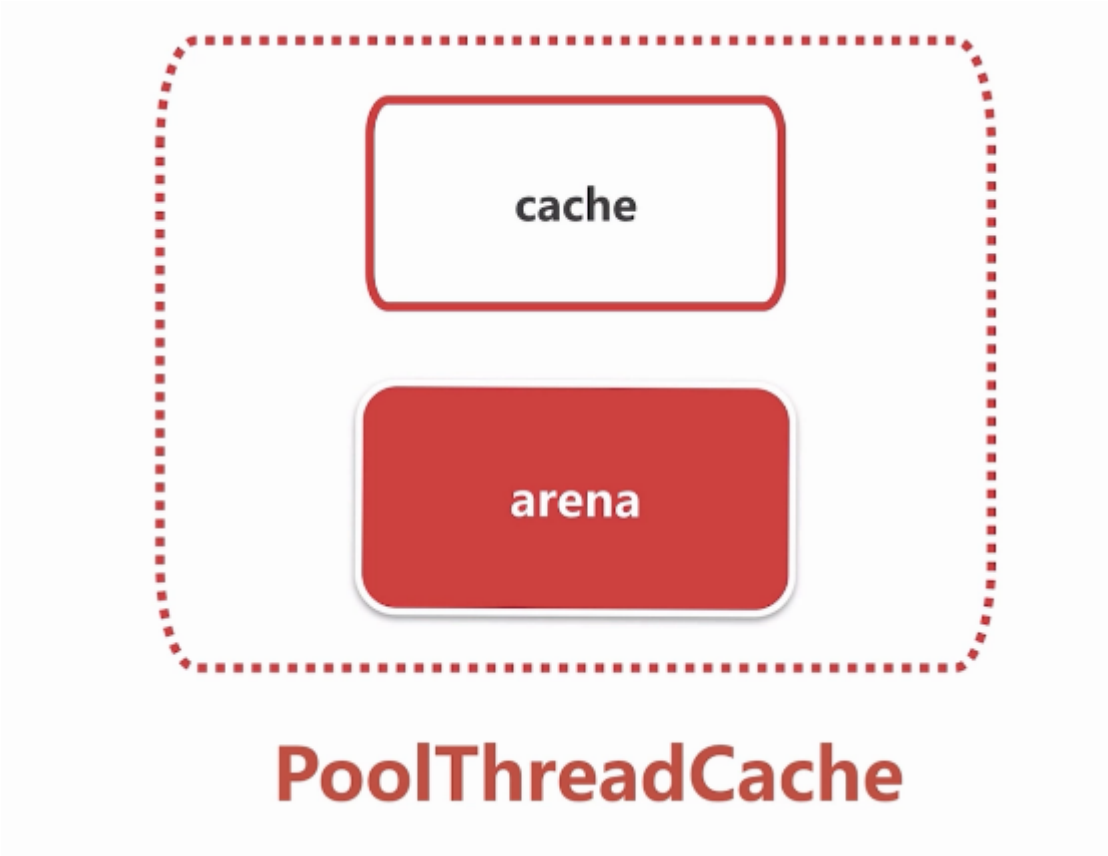
```
public final boolean allocate(PooledByteBuf<T> buf, int reqCapacity) {
    Entry<T> entry = queue.poll();
    if (entry == null) {
        return false;
    }
    initBuf(entry.chunk, entry.handle, buf, reqCapacity);
    entry.recycle();

    // allocations is not thread-safe which is fine as this is only called from the same
thread all time.
    ++ allocations;
    return true;
}
```

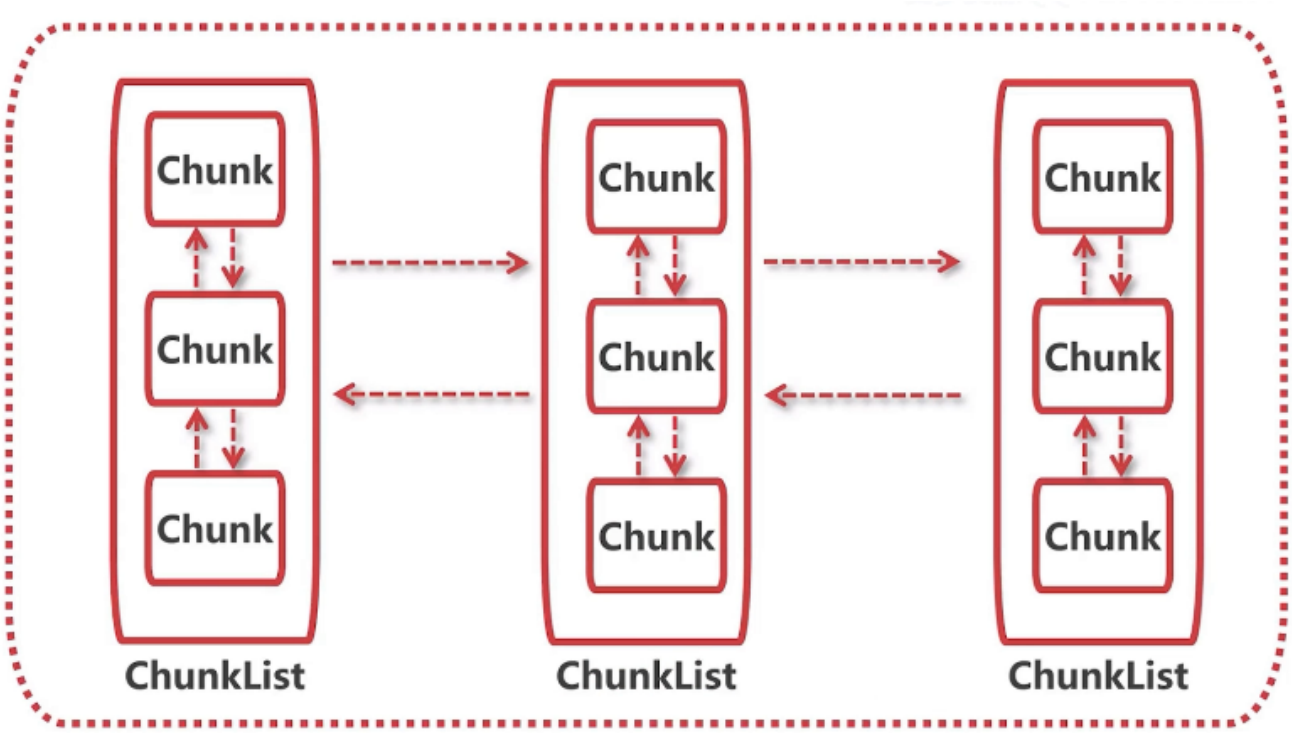
io.netty.util.Recycler.DefaultHandle#recycle

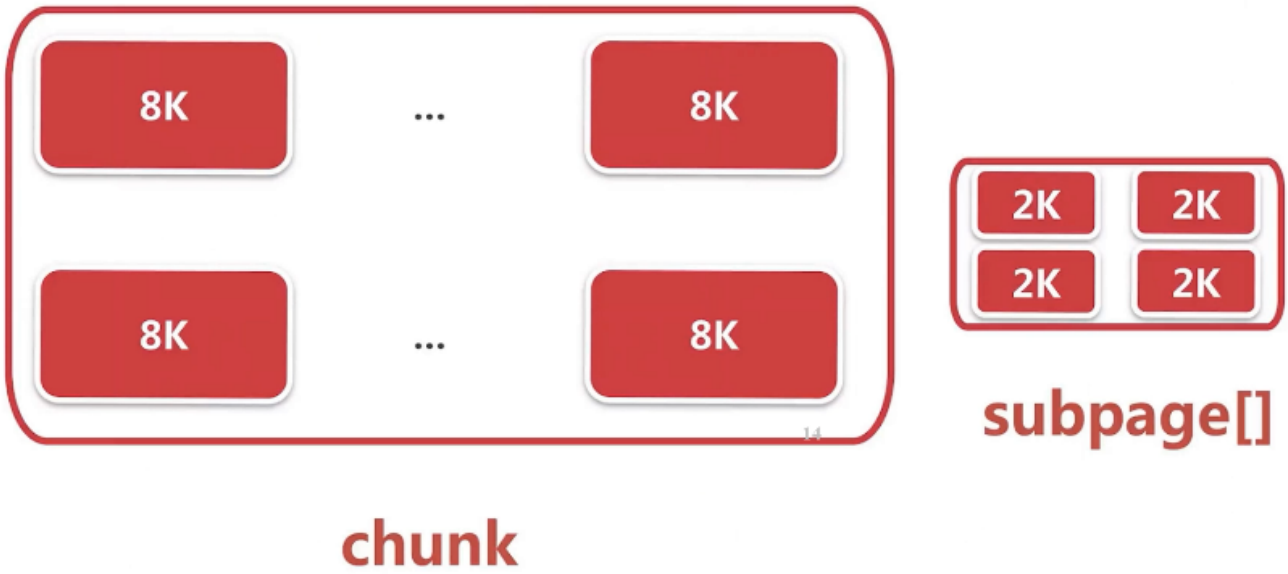
```
public void recycle(Object object) {
    if (object != value) {
        throw new IllegalArgumentException("object does not belong to handle");
    }
    stack.push(this);
}
```

7.12 Arena、Chunk、Page、Subpage概念



Arena数据结构：






```
abstract class PoolArena<T> implements PoolArenaMetric {
    static final boolean HAS_UNSAFE = PlatformDependent.hasUnsafe();

    enum SizeClass {
        Tiny,
        Small,
        Normal
    }

    static final int numTinySubpagePools = 512 >>> 4;
```

```
    final PooledByteBufAllocator parent;

    private final int maxOrder;
    final int pageSize;
    final int pageShifts;
    final int chunkSize;
    final int subpageOverflowMask;
    final int numSmallSubpagePools;
    private final PoolSubpage<T>[] tinySubpagePools;
    private final PoolSubpage<T>[] smallSubpagePools;

    private final PoolChunkList<T> q050;
    private final PoolChunkList<T> q025;
    private final PoolChunkList<T> q000;
    private final PoolChunkList<T> qInit;
    private final PoolChunkList<T> q075;
    private final PoolChunkList<T> q100;
    ...
}
```

```
//PoolSubpage 数据结构 双向链表
final class PoolSubpage<T> implements PoolSubpageMetric {
    ...
    PoolSubpage<T> prev;
    PoolSubpage<T> next;
    ...
}
```

内存分配的流程：

从一个线程的PoolThreadCache中获取对应的Arena，Arena再通过PoolChunkList里面去一个chunk，

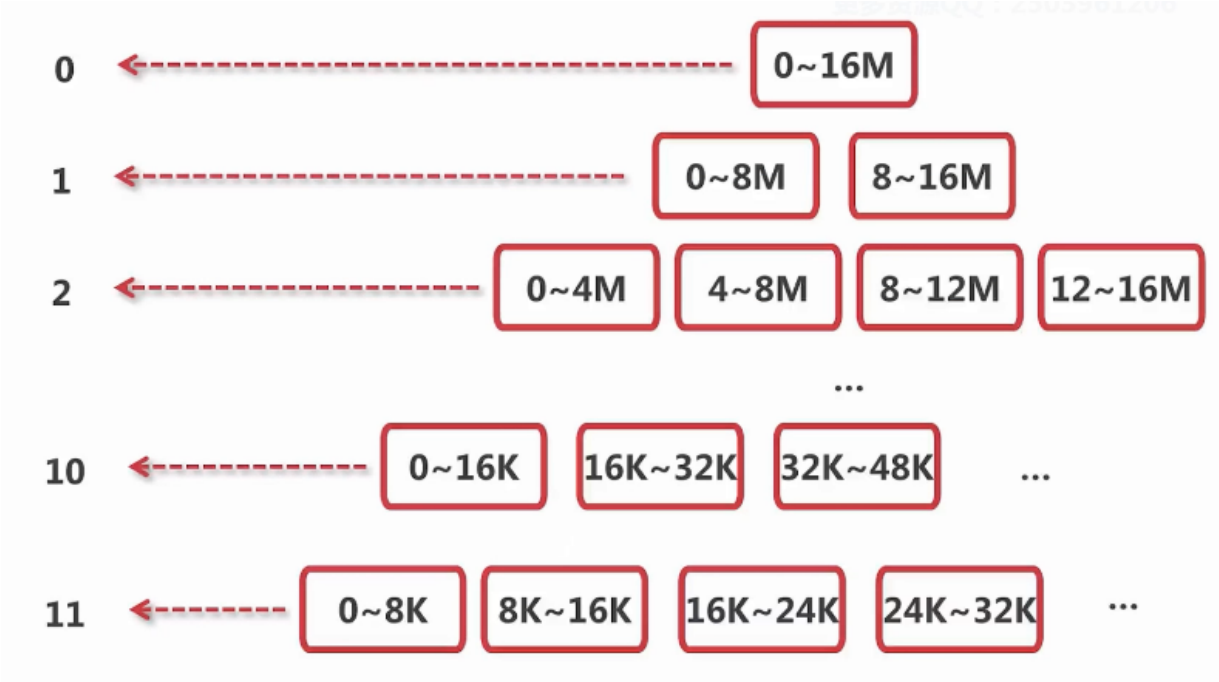
chunk会判断内存分配大小：

超过1个page，则以page为单位；若远小于一个page，则将一个page切分成多个子page进行内存划分。

7.13 page 级别内存分配 allocateNormal()

- 尝试在现有的chunk上分配
- 创建一个chunk进行内存分配
- 初始化pooledByteBuf

  一个chunk最终是以K为单位组织内存的，chunk中的每一个节点可以标识对应的这块内存是否被使用



io.netty.buffer.PoolArena#allocateNormal

```
private synchronized void allocateNormal(PooledByteBuf<T> buf, int reqCapacity, int
normCapacity) {
    if (q050.allocate(buf, reqCapacity, normCapacity) || q025.allocate(buf, reqCapacity,
normCapacity) ||
        q000.allocate(buf, reqCapacity, normCapacity) || qInit.allocate(buf, reqCapacity,
normCapacity) ||
        q075.allocate(buf, reqCapacity, normCapacity)) {
        ++allocationsNormal;
        return;
    }

    // Add a new chunk.
    PoolChunk<T> c = newChunk(pageSize, maxOrder, pageShifts, chunkSize);
    long handle = c.allocate(normCapacity);
    ++allocationsNormal;
    assert handle > 0;
    c.initBuf(buf, handle, reqCapacity);
    qInit.add(c);
}
```

7.14 subpage 级别的内存分配 allocateTiny()

- 定位一个Subpage对象
- 初始化Subpage
- 初始化PooledByteBuf

io.netty.buffer.PoolChunk#allocateSubpage

```
private long allocateSubpage(int normCapacity) {
    // Obtain the head of the PoolSubPage pool that is owned by the PoolArena and
synchronize on it.
    // This is need as we may add it back and so alter the linked-list structure.
    PoolSubpage<T> head = arena.findSubpagePoolHead(normCapacity);
    synchronized (head) {
        int d = maxOrder; // subpages are only be allocated from pages i.e., leaves
        int id = allocateNode(d);
        if (id < 0) {
            return id;
        }

        final PoolSubpage<T>[] subpages = this.subpages;
        final int pageSize = this.pageSize;

        freeBytes -= pageSize;

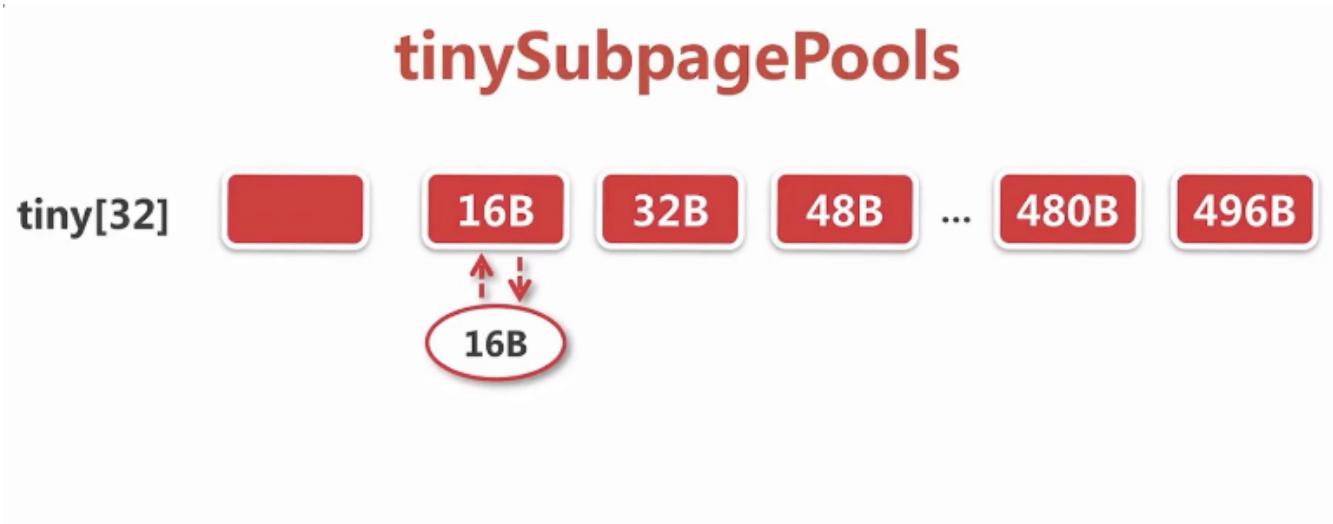
        int subpageIdx = subpageIdx(id);
        PoolSubpage<T> subpage = subpages[subpageIdx];
        if (subpage == null) {
            subpage = new PoolSubpage<T>(head, this, id, runOffset(id), pageSize,
normCapacity);
            subpages[subpageIdx] = subpage;
        } else {
            subpage.init(head, normCapacity);
        }
        return subpage.allocate();
    }
}
```

io.netty.buffer.PoolSubpage#init

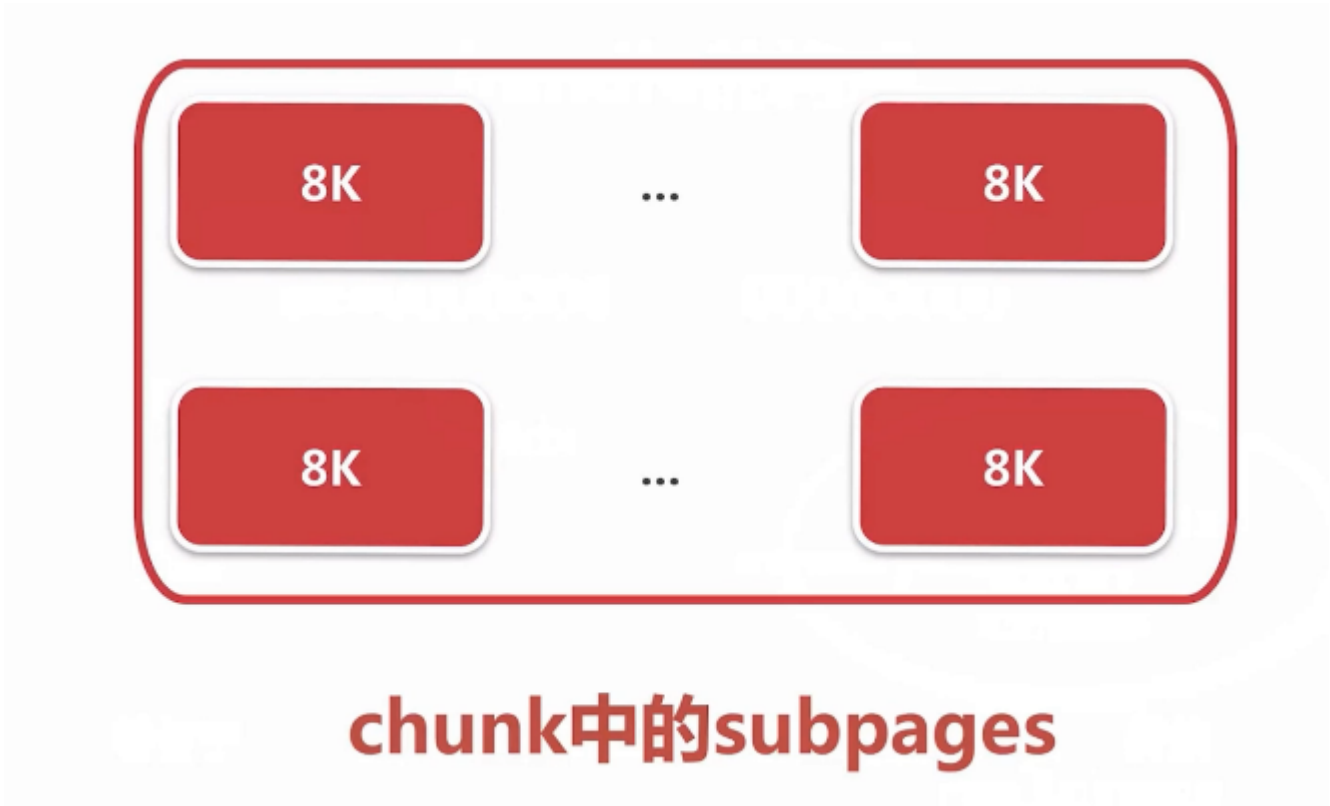
```
PoolSubpage(PoolSubpage<T> head, PoolChunk<T> chunk, int memoryMapIdx, int runOffset, int
pageSize, int elemSize) {
    this.chunk = chunk;
    this.memoryMapIdx = memoryMapIdx;
    this.runOffset = runOffset;
    this.pageSize = pageSize;
    bitmap = new long[pageSize >>> 10]; // pageSize / 16 / 64
    init(head, elemSize);
}

void init(PoolSubpage<T> head, int elemSize) {
    doNotDestroy = true;
    this.elemSize = elemSize;
    if (elemSize != 0) {
        maxNumElems = numAvail = pageSize / elemSize;
        nextAvail = 0;
        bitmapLength = maxNumElems >>> 6;
        if ((maxNumElems & 63) != 0) {
            bitmapLength ++;
        }
```

```
        for (int i = 0; i < bitmapLength; i ++) {
            bitmap[i] = 0;//标识哪个子page已经被分配
        }
    }
    addToPool(head);
}
```



chunk中的subpages



io.netty.buffer.PoolSubpage#allocate

```
//从位图中找到一个未被使用的subpage
long allocate() {
    if (elemSize == 0) {
        return toHandle(0);
    }

    if (numAvail == 0 || !doNotDestroy) {
        return -1;
    }

    final int bitmapIdx = getNextAvail();
    int q = bitmapIdx >>> 6;
    int r = bitmapIdx & 63;
    assert (bitmap[q] >>> r & 1) == 0;
    bitmap[q] |= 1L << r;

    if (-- numAvail == 0) {
        removeFromPool();
    }
    return toHandle(bitmapIdx);
}
```

io.netty.buffer.PoolSubpage#toHandle

```
private long toHandle(int bitmapIdx) {
    return 0x4000000000000000L | (long) bitmapIdx << 32 | memoryMapIdx;
}
```

Handle的构成**

io.netty.buffer.PoolChunk#initBufWithSubpage(io.netty.buffer.PooledByteBuf, long, int, int)

```
private void initBufWithSubpage(PooledByteBuf<T> buf, long handle, int bitmapIdx, int
reqCapacity) {
    assert bitmapIdx != 0;

    int memoryMapIdx = memoryMapIdx(handle);

    PoolSubpage<T> subpage = subpages[subpageIdx(memoryMapIdx)];
    assert subpage.doNotDestroy;
    assert reqCapacity <= subpage.elemSize;

    buf.init(
        this, handle,
        //page的偏移量 + subpage的偏移量 = 整个内存的偏移量 再给到bytebuf,
        //这样bytebuf就可以基于这个偏移量进行读写
        runOffset(memoryMapIdx) + (bitmapIdx & 0x3FFFFFFF) * subpage.elemSize, reqCapacity,
subpage.elemSize,
        arena.parent.threadCache());
}
```

7.15 ByteBuf的回收

```
public class AllocatorDemo {
    public static void main(String[] args) {
        PooledByteBufAllocator allocator = PooledByteBufAllocator.DEFAULT;
        //申请一块内存
        ByteBuf byteBuf = allocator.directBuffer(16);
        //释放内存
        byteBuf.release();
    }
}
```

io.netty.buffer.AbstractReferenceCountedByteBuf#release()

```
public boolean release() {
    return release0(1);
}
```

io.netty.buffer.PooledByteBuf#deallocate

```
protected final void deallocate() {
    if (handle >= 0) {
        final long handle = this.handle;
        this.handle = -1;
        memory = null;
        chunk.arena.free(chunk, handle, maxLength, cache);
        recycle();
    }
}
```

ByteBuf的释放分析：

- 连续的内存区段加到缓存

  io.netty.buffer.PoolThreadCache#cache(io.netty.buffer.PoolArena<?>, int, io.netty.buffer.PoolArena.SizeClass)

  ```
  boolean add(PoolArena<?> area, PoolChunk chunk, long handle, int normCapacity,
  SizeClass sizeClass) {
          MemoryRegionCache<?> cache = cache(area, normCapacity, sizeClass);
          if (cache == null) {
              return false;
          }
          return cache.add(chunk, handle);
  }


  private MemoryRegionCache<?> cache(PoolArena<?> area, int normCapacity, SizeClass
  sizeClass) {
      switch (sizeClass) {
      case Normal:
          return cacheForNormal(area, normCapacity);
      case Small:
          return cacheForSmall(area, normCapacity);
  ```

```
    case Tiny:
        return cacheForTiny(area, normCapacity);
    default:
        throw new Error();
    }
}
```

io.netty.buffer.PoolThreadCache.MemoryRegionCache#add

```
public final boolean add(PoolChunk<T> chunk, long handle) {
    Entry<T> entry = newEntry(chunk, handle);
    boolean queued = queue.offer(entry);
    if (!queued) {
        // If it was not possible to cache the chunk, immediately recycle the entry
        entry.recycle();
    }
    return queued;
}
```

- 标记连续的内存区段为未使用
    - page级别
    - subPage级别

io.netty.buffer.PoolChunkList#free

```
boolean free(PoolChunk<T> chunk, long handle) {
    chunk.free(handle);
    if (chunk.usage() < minUsage) {
        remove(chunk);
        // Move the PoolChunk down the PoolChunkList linked-list.
        return move0(chunk);
    }
    return true;
}
```

io.netty.buffer.PoolChunk#free

```
void free(long handle) {
    int memoryMapIdx = memoryMapIdx(handle);
    int bitmapIdx = bitmapIdx(handle);

    if (bitmapIdx != 0) { // free a subpage
        PoolSubpage<T> subpage = subpages[subpageIdx(memoryMapIdx)];
        assert subpage != null && subpage.doNotDestroy;

        // Obtain the head of the PoolSubPage pool that is owned by the PoolArena
and synchronize on it.
        // This is need as we may add it back and so alter the linked-list
structure.
        PoolSubpage<T> head = arena.findSubpagePoolHead(subpage.elemSize);
        synchronized (head) {
```

```
            if (subpage.free(head, bitmapIdx & 0x3FFFFFFF)) {
                return;
            }
        }
    }
    freeBytes += runLength(memoryMapIdx);
    setValue(memoryMapIdx, depth(memoryMapIdx));
    updateParentsFree(memoryMapIdx);
}
```

- ByteBuf加到对象池

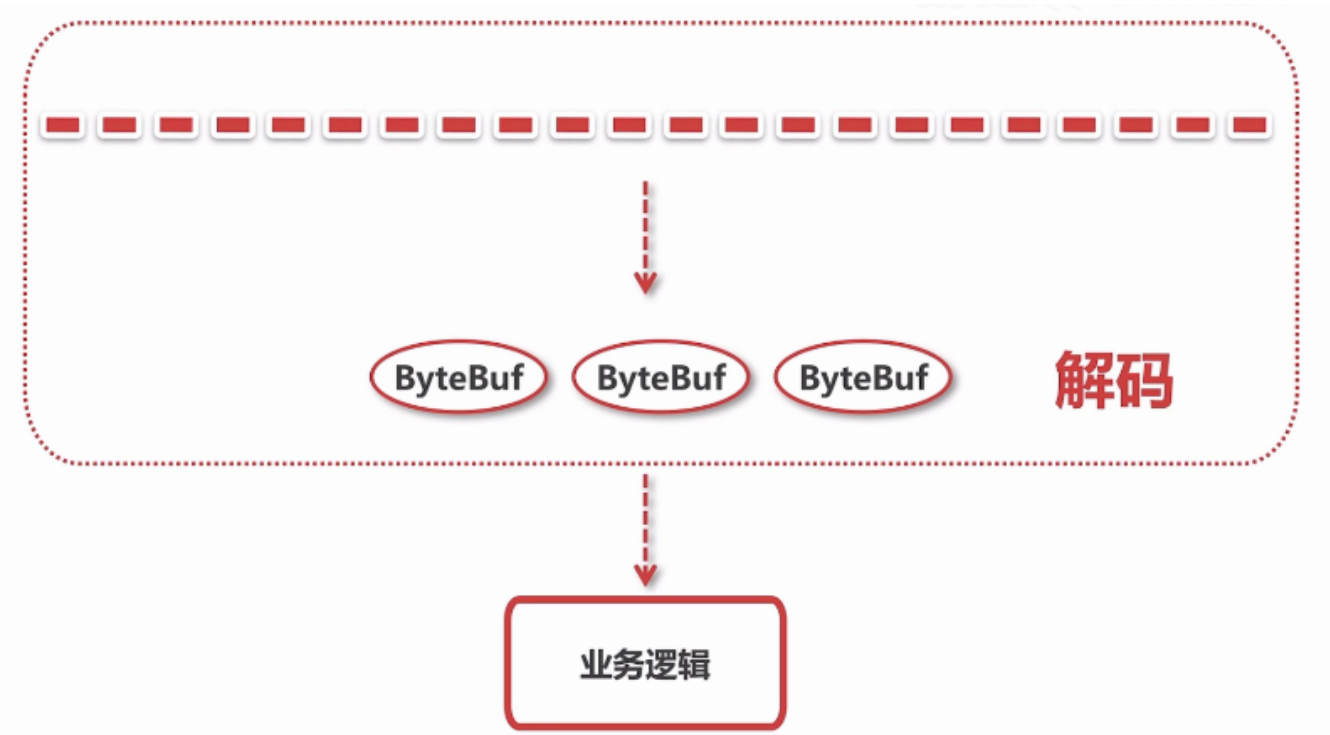
  bytebuf可能会经常被申请和释放，如果qps高的时候可能会产生很多的bytebuf对象，为了尽可能的减少GC，netty使用对象池技术，当申请byteBuf的时候尽可能从对象池中取，当释放byteBuf的时候，将其放到对象池中。

7.16 ByteBuf 总结

- ByteBuf的api和分类
- 分配pooled内存的总步骤
- 不同规格的pooled内存分配与释放

八. Netty 解码

解码：把一串二级制数据流解析成一个个自定义的数据包即Bytebuf，后续业务处理都基于bytebuf。



8.1 .1思考问题

- 解码器抽象的解码过程
- netty中有哪些拆箱即用的解码器

8.1.2 本章内容

- 解码器基类实现抽象解码的过程
- netty中常见的解码器分析

8.2 解码器的基类 - ByteToMessageDecoder解码步骤

暴漏decode抽象方法，具体实现交给子类。好处是：不同的子类的协议可以有自定义的decode方法，而最外层解码的框架都是一致的。

- 累加字节流
- 调用子类的decode方法进行解析
- 将解析到的ByteBuf向下传播

io.netty.handler.codec.ByteToMessageDecoder#channelRead

```
public void channelRead(ChannelHandlerContext ctx, Object msg) throws Exception {
    if (msg instanceof ByteBuf) {
        CodecOutputList out = CodecOutputList.newInstance();
        try {
            ByteBuf data = (ByteBuf) msg;
            first = cumulation == null;
            if (first) {
                cumulation = data;
            } else {
                //当前累加器里的数据和读进来数据进行累加 - 注意累加器的扩容逻辑
                cumulation = cumulator.cumulate(ctx.alloc(), cumulation, data);
            }
            // out 用来接收从cumulation中解析到的对象
            callDecode(ctx, cumulation, out);
        } catch (DecoderException e) {
            throw e;
        } catch (Throwable t) {
            throw new DecoderException(t);
        } finally {
            if (cumulation != null && !cumulation.isReadable()) {
                numReads = 0;
                cumulation.release();
                cumulation = null;
            } else if (++ numReads >= discardAfterReads) {
                // We did enough reads already try to discard some bytes so we not risk to
see a OOME.
                // See https://github.com/netty/netty/issues/4275
                numReads = 0;
                discardSomeReadBytes();
            }

            int size = out.size();
            decodeWasNull = !out.insertSinceRecycled();
            // 讲解析到的对象向下传播到业务解码器
            fireChannelRead(ctx, out, size);
            out.recycle();
        }
    } else {
        ctx.fireChannelRead(msg);
```

```
    }
}
```

io.netty.handler.codec.ByteToMessageDecoder#callDecode

```
protected void callDecode(ChannelHandlerContext ctx, ByteBuf in, List<Object> out) {
    try {
        while (in.isReadable()) {
            int outSize = out.size();

            if (outSize > 0) {
                fireChannelRead(ctx, out, outSize);
                out.clear();

                // Check if this handler was removed before continuing with decoding.
                // If it was removed, it is not safe to continue to operate on the buffer.
                //
                // See:
                // - https://github.com/netty/netty/issues/4635
                if (ctx.isRemoved()) {
                    break;
                }
                outSize = 0;
            }

            int oldInputLength = in.readableBytes();
            decode(ctx, in, out);

            // Check if this handler was removed before continuing the loop.
            // If it was removed, it is not safe to continue to operate on the buffer.
            //
            // See https://github.com/netty/netty/issues/1664
            if (ctx.isRemoved()) {
                break;
            }
            //未解析到对象
            if (outSize == out.size()) {
                if (oldInputLength == in.readableBytes()) {
                    break;
                } else {
                    continue;
                }
            }
            if (oldInputLength == in.readableBytes()) {
                throw new DecoderException(
                        StringUtil.simpleClassName(getClass()) +
                        ".decode() did not read anything but decoded a message.");
            }

            if (isSingleDecode()) {
                break;
            }
        }
```

```
    } catch (DecoderException e) {
        throw e;
    } catch (Throwable cause) {
        throw new DecoderException(cause);
    }
}
```

8.3 基于固定长度解码器分析

io.netty.handler.codec.FixedLengthFrameDecoder

```
/**
 * A decoder that splits the received {@link ByteBuf}s by the fixed number
 * of bytes. For example, if you received the following four fragmented packets:
 * <pre>
 * +---+----+------+----+
 * | A | BC | DEFG | HI |
 * +---+----+------+----+
 * </pre>
 * A {@link FixedLengthFrameDecoder}{@code (3)} will decode them into the
 * following three packets with the fixed length:
 * <pre>
 * +-----+-----+-----+
 * | ABC | DEF | GHI |
 * +-----+-----+-----+
 * </pre>
 */
public class FixedLengthFrameDecoder extends ByteToMessageDecoder {

    //按frameLength的长度为分割进行解析
    private final int frameLength;

    /**
     * Creates a new instance.
     *
     * @param frameLength the length of the frame
     */
    public FixedLengthFrameDecoder(int frameLength) {
        if (frameLength <= 0) {
            throw new IllegalArgumentException(
                    "frameLength must be a positive integer: " + frameLength);
        }
        this.frameLength = frameLength;
    }

    @Override
    protected final void decode(ChannelHandlerContext ctx, ByteBuf in, List<Object> out)
throws Exception {
        Object decoded = decode(ctx, in);
        if (decoded != null) {
            out.add(decoded);
        }
    }
```

```
    /**
     * Create a frame out of the {@link ByteBuf} and return it.
     *
     * @param   ctx             the {@link ChannelHandlerContext} which this {@link
ByteToMessageDecoder} belongs to
     * @param   in              the {@link ByteBuf} from which to read data
     * @return  frame           the {@link ByteBuf} which represent the frame or {@code
null} if no frame could
     *                          be created.
     */
    protected Object decode(
            @SuppressWarnings("UnusedParameters") ChannelHandlerContext ctx, ByteBuf in)
throws Exception {
        //当前累加器可读字节 < frameLength
        if (in.readableBytes() < frameLength) {
            return null;
        } else {
            //从当前累加器截取frameLength个字节进行解析
            return in.readRetainedSlice(frameLength);
        }
    }
}
```

8.4 基于行解码器分析

io.netty.handler.codec.LineBasedFrameDecoder

发过来的字节流是以 \r \n 或直接以 \n 结尾的字节流，该解码器的功能就是以 换行符 为分割，将字节流解析成完整的数据包。

回车、换行的区别

在Windows中：

‘\r’（回车）：即将光标回到当前行的行首(而不会换到下一行)，之后的输出会把之前的输出覆盖

‘\n’ 换行，换到当前位置的下一位置，而不会回到行首；

Unix系统里，每行结尾只有“<换行>”，即"\n";

Windows系统里面，每行结尾是“<回车><换行>”，即“\r\n”;

Mac系统里，每行结尾是“<回车>”，即"\r";

也就是：
Linux中遇到换行符("\n")会进行回车+换行的操作，回车符（“\r”）反而只会作为控制字符("^M")显示，不发生回车的操作。
而windows中要回车符+换行符("\r\n")才会回车+换行，缺少一个控制符或者顺序不对都不能正确的另起一行。

LineBasedFrameDecoder 支持两种格式的换行符；

以\n 结尾 eol指向 \n

若以 \r \n 结尾， 会把\r \n 当作整体作为换行符， eol指向 \r


```
public class LineBasedFrameDecoder extends ByteToMessageDecoder {

    /** Maximum length of a frame we're willing to decode.
        能接收的最大字节
    */
    private final int maxLength;
    /** Whether or not to throw an exception as soon as we exceed maxLength.
        超过能接收的最大字节是否马上抛出异常
    */
    private final boolean failFast;
    /**
        最终解析出来的数据包是否带换行符，为true表示不带换行符
    */
    private final boolean stripDelimiter;

    /** True if we're discarding input because we're already over maxLength.  */
    private boolean discarding;
    private int discardedBytes;
}


......

     protected final void decode(ChannelHandlerContext ctx, ByteBuf in, List<Object> out)
throws Exception {
        Object decoded = decode(ctx, in);
        if (decoded != null) {
            out.add(decoded);
        }
```

```
    }

......

    protected Object decode(ChannelHandlerContext ctx, ByteBuf buffer) throws Exception {
        final int eol = findEndOfLine(buffer);
        if (!discarding) {
            if (eol >= 0) {
                final ByteBuf frame;
                final int length = eol - buffer.readerIndex();
                final int delimLength = buffer.getByte(eol) == '\r'? 2 : 1;

                if (length > maxLength) {
                    buffer.readerIndex(eol + delimLength);
                    fail(ctx, length);
                    return null;
                }

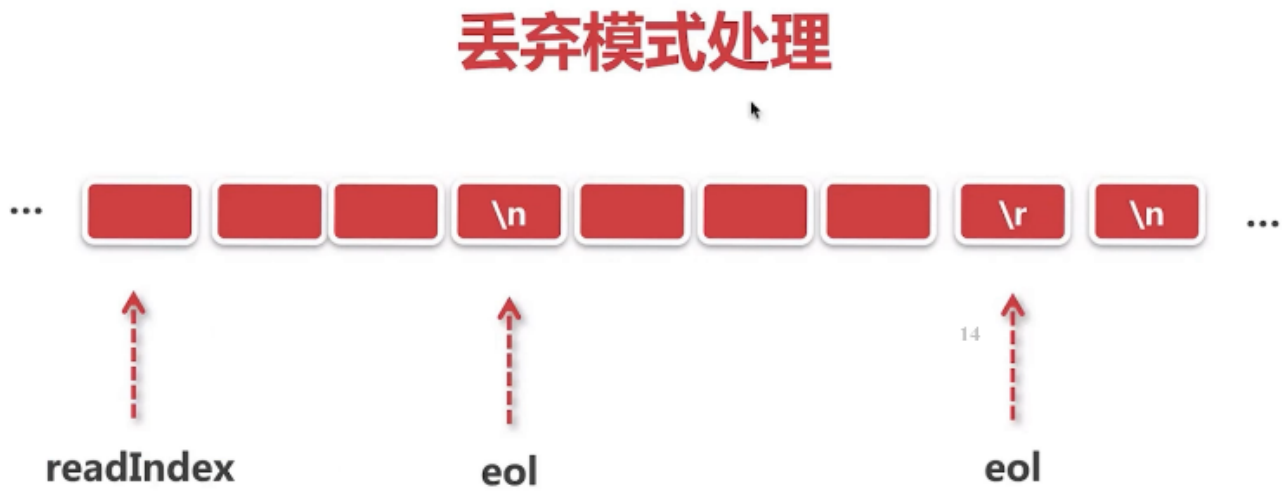
                if (stripDelimiter) {
                    frame = buffer.readRetainedSlice(length);
                    buffer.skipBytes(delimLength);
                } else {
                    frame = buffer.readRetainedSlice(length + delimLength);
                }

                return frame;
            } else {
                final int length = buffer.readableBytes();
                if (length > maxLength) {
                    discardedBytes = length;
                    buffer.readerIndex(buffer.writerIndex());
                    discarding = true;
                    if (failFast) {
                        fail(ctx, "over " + discardedBytes);
                    }
                }
                return null;
            }
        } else {
            if (eol >= 0) {
                final int length = discardedBytes + eol - buffer.readerIndex();
                final int delimLength = buffer.getByte(eol) == '\r'? 2 : 1;
                buffer.readerIndex(eol + delimLength);
                discardedBytes = 0;
                discarding = false;
                if (!failFast) {
                    fail(ctx, length);
                }
            } else {
                discardedBytes += buffer.readableBytes();
                buffer.readerIndex(buffer.writerIndex());
            }
            return null;
```

```
        }
    }

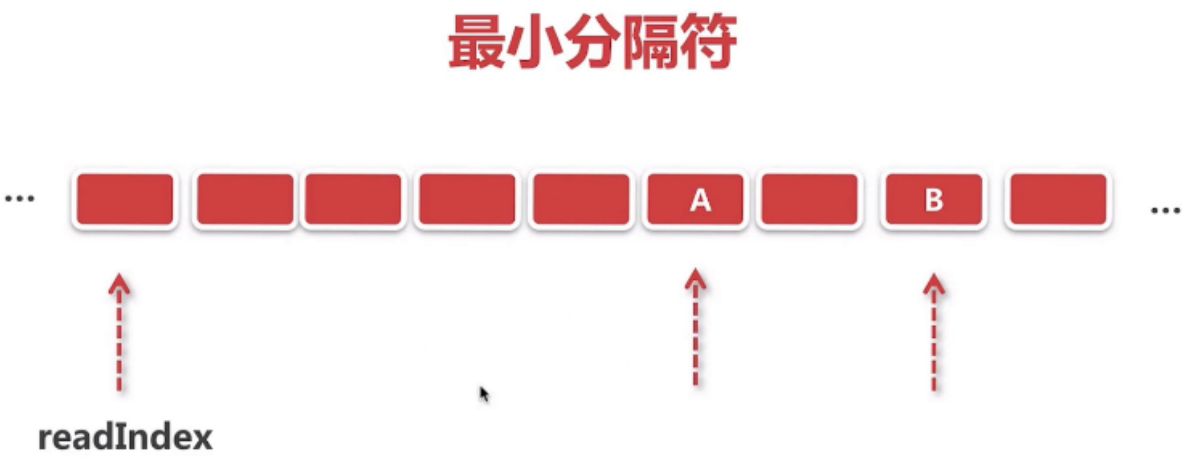
.......

    /**
     * Returns the index in the buffer of the end of line found.
     * Returns -1 if no end of line was found in the buffer.
     */
    private static int findEndOfLine(final ByteBuf buffer) {
        int i = buffer.forEachByte(ByteProcessor.FIND_LF);
        if (i > 0 && buffer.getByte(i - 1) == '\r') {
            i--;
        }
        return i;
    }
```

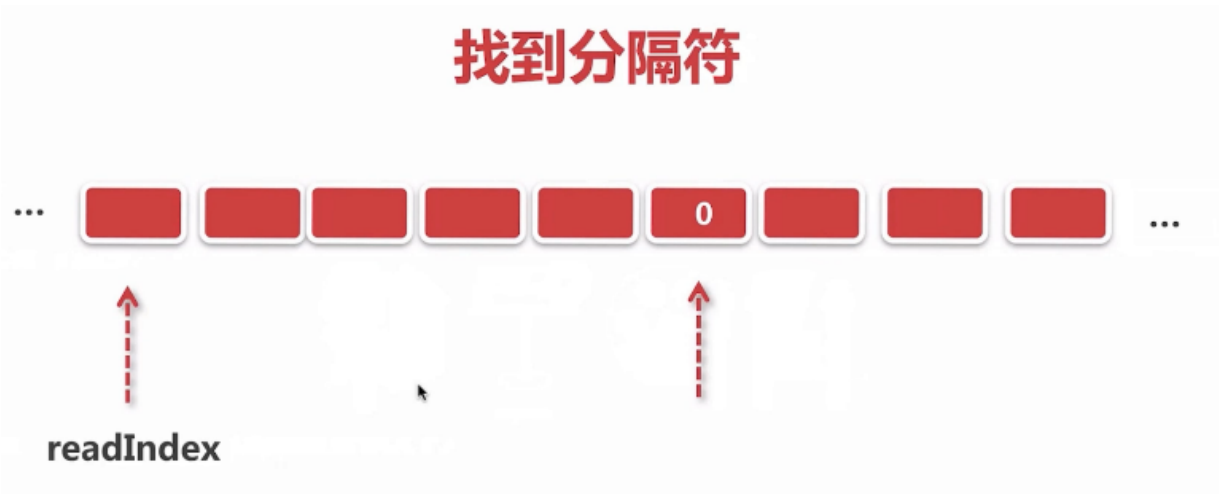


8.5 基于固定分隔符解码器分析

- 行处理器
    - 若分隔符为换行符则直接使用行处理器
- 找到最小分隔符



- 解码



传进来的二进制字节流带有一系列的分隔符，经过这个解码器处理，可以分拆成一个个完整的数据包。

io.netty.handler.codec.DelimiterBasedFrameDecoder

```
protected Object decode(ChannelHandlerContext ctx, ByteBuf buffer) throws Exception {
    if (lineBasedDecoder != null) {
        return lineBasedDecoder.decode(ctx, buffer);
    }
    // Try all delimiters and choose the delimiter which yields the shortest frame.
    int minFrameLength = Integer.MAX_VALUE;
    ByteBuf minDelim = null;
    for (ByteBuf delim: delimiters) {
        int frameLength = indexOf(buffer, delim);
        if (frameLength >= 0 && frameLength < minFrameLength) {
            minFrameLength = frameLength;
            minDelim = delim;
        }
    }

    if (minDelim != null) {
        int minDelimLength = minDelim.capacity();
        ByteBuf frame;

        if (discardingTooLongFrame) {
            // We've just finished discarding a very large frame.
            // Go back to the initial state.
            discardingTooLongFrame = false;
            buffer.skipBytes(minFrameLength + minDelimLength);

            int tooLongFrameLength = this.tooLongFrameLength;
            this.tooLongFrameLength = 0;
            if (!failFast) {
                fail(tooLongFrameLength);
            }
            return null;
        }
```

```
        if (minFrameLength > maxFrameLength) {
            // Discard read frame.
            buffer.skipBytes(minFrameLength + minDelimLength);
            fail(minFrameLength);
            return null;
        }

        if (stripDelimiter) {
            frame = buffer.readRetainedSlice(minFrameLength);
            buffer.skipBytes(minDelimLength);
        } else {
            frame = buffer.readRetainedSlice(minFrameLength + minDelimLength);
        }

        return frame;
    } else {
        if (!discardingTooLongFrame) {
            if (buffer.readableBytes() > maxFrameLength) {
                // Discard the content of the buffer until a delimiter is found.
                tooLongFrameLength = buffer.readableBytes();
                buffer.skipBytes(buffer.readableBytes());
                discardingTooLongFrame = true;
                if (failFast) {
                    fail(tooLongFrameLength);
                }
            }
        } else {
            // Still discarding the buffer since a delimiter is not found.
            tooLongFrameLength += buffer.readableBytes();
            buffer.skipBytes(buffer.readableBytes());
        }
        return null;
    }
}
```

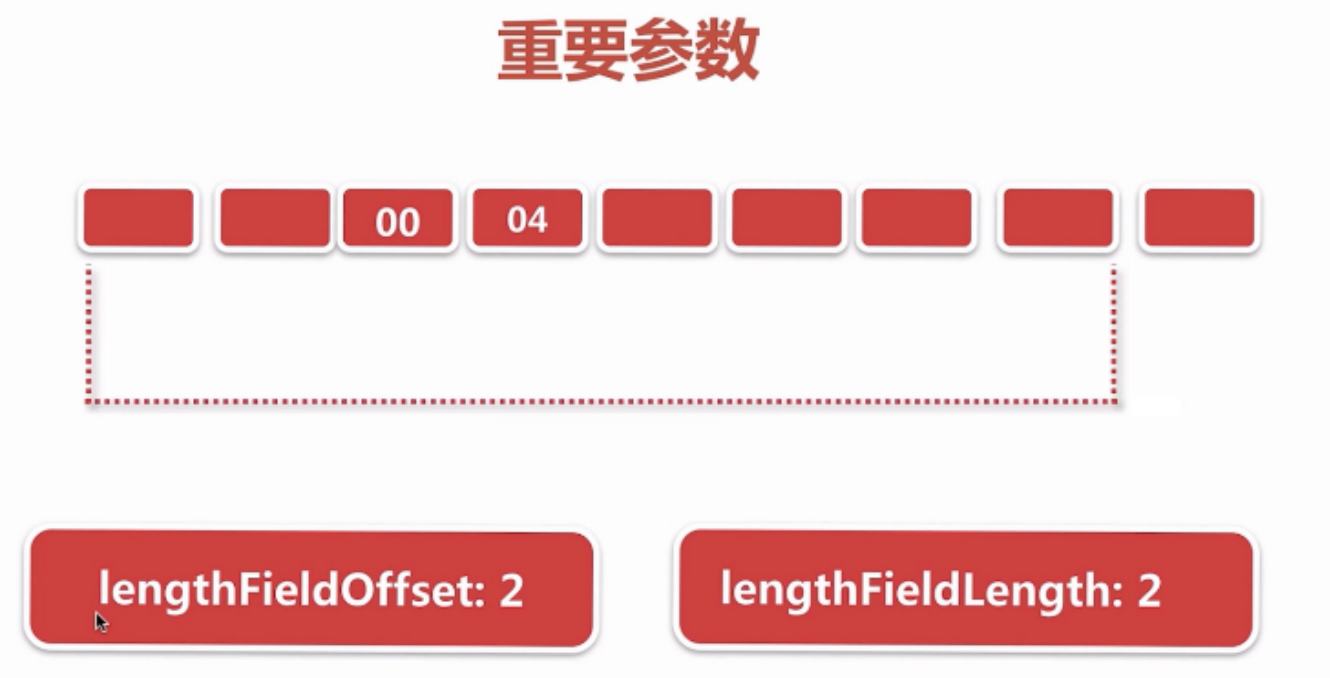
8.6 基于长度域解码器分析 - 最为常用

lengthFieldOffset:长度域在二进制数据流中的偏移量是多少

lengthFieldLength:从长度域开始往后的几个字节组合起来表表示长度

lengthAdjustment：

initialBytesToStrip：



io.netty.handler.codec.LengthFieldBasedFrameDecoder

```
/**
 * <b>lengthFieldOffset</b>   = <b>0</b>
 * <b>lengthFieldLength</b>   = <b>2</b>
 * lengthAdjustment    = 0
 * initialBytesToStrip = 0 (= do not strip header)
 *
 * BEFORE DECODE (14 bytes)         AFTER DECODE (14 bytes)
 * +--------+----------------+      +--------+----------------+
 * | Length | Actual Content |----->| Length | Actual Content |
 * | 0x000C | "HELLO, WORLD" |      | 0x000C | "HELLO, WORLD" |
 * +--------+----------------+      +--------+----------------+
 * ......
*/
public class LengthFieldBasedFrameDecoder extends ByteToMessageDecoder {

    private final ByteOrder byteOrder;
    private final int maxFrameLength;
    private final int lengthFieldOffset;
    private final int lengthFieldLength;
    private final int lengthFieldEndOffset;
    private final int lengthAdjustment;
    private final int initialBytesToStrip;
    private final boolean failFast;
    private boolean discardingTooLongFrame;
    private long tooLongFrameLength;
    private long bytesToDiscard;
}
```

8.7 基于长度域解码器步骤

- 计算要抽取的数据包长度

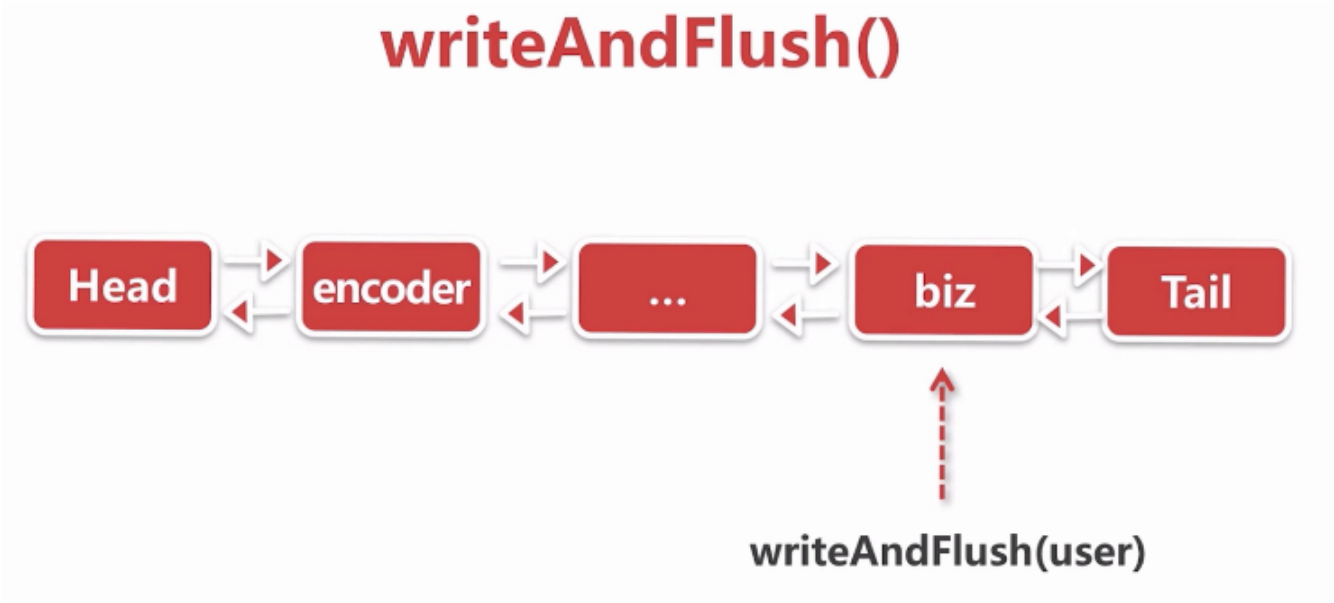
- 跳过字节逻辑处理
- 丢弃模式下的处理

8.8 解码器总结

九. netty 编码

9.1 问题：如何把对象变成字节流，最终写到socket底层

- encode() ——分别ByteBuf对象，encoder调用抽象的encode方法将接收到的数据填充到ByteBuf对象
- write() ——传递到Head节点，通过底层unsafe将当前的byteBuf塞到Unsafe底层维护的一个缓冲区对象中，同时计算写缓冲区数据是否超过高水位，若写缓冲区中可写的字计数 > 64 K, 就改变channel的状态为不可写
- flush() ——传递到Head节点，调用unsafe的flush方法，调整指针 -》通过for循环不断从写缓冲区拿byteBuf -》转化成JDK底层可以接收的ByteBuffer-》通过JDK的channel将byteBuffer写出去-》将写完一个将缓冲区中当前节点进行删除-》若写缓冲区中可写的字计数 < 32 K, 就改变channel的状态为可写




```
/**
 * @Auther: leh
 * @Date: 2019/11/15 15:55
 * @Description: 将user对象编码
 * ---------------------
 * |   4    |  4  |  ?   |
 * ---------------------
 * | length | age | name |
 * ---------------------
 */
public class Encoder extends MessageToByteEncoder<User> {
    @Override
    protected void encode(ChannelHandlerContext ctx, User user, ByteBuf out) throws
Exception {
        byte[] bytes = user.getName().getBytes();
        out.writeInt(4 + bytes.length);
        out.writeInt(user.getAge());
        out.writeBytes(bytes);
    }
}
```

9.2 writeAndFlush 抽象步骤

- 从tail节点开始往前传播
- 逐个调用channelHanler的write方法
- 逐个调用channelHandler的flush方法 - 真正写到底层去

```
public class BizHandler extends ChannelInboundHandlerAdapter {
    @Override
    public void channelRead(ChannelHandlerContext ctx, Object msg) throws Exception {
        User user = new User(18, "zhangsan");
        ctx.channel().writeAndFlush(user);
    }
}
```

io.netty.channel.AbstractChannelHandlerContext#writeAndFlush(java.lang.Object, io.netty.channel.ChannelPromise)

```
public ChannelFuture writeAndFlush(Object msg, ChannelPromise promise) {
    if (msg == null) {
        throw new NullPointerException("msg");
    }

    if (!validatePromise(promise, true)) {
        ReferenceCountUtil.release(msg);
        // cancelled
        return promise;
    }

    write(msg, true, promise);

    return promise;
}

...

private void write(Object msg, boolean flush, ChannelPromise promise) {
        AbstractChannelHandlerContext next = findContextOutbound();
        final Object m = pipeline.touch(msg, next);
        EventExecutor executor = next.executor();
        if (executor.inEventLoop()) {
            if (flush) {
                next.invokeWriteAndFlush(m, promise);
            } else {
                next.invokeWrite(m, promise);
            }
        } else {
            AbstractWriteTask task;
            if (flush) {
                task = WriteAndFlushTask.newInstance(next, m, promise);
            }  else {
                task = WriteTask.newInstance(next, m, promise);
            }
            safeExecute(executor, task, promise, m);
        }
    }

...

 private void invokeWriteAndFlush(Object msg, ChannelPromise promise) {
        if (invokeHandler()) {
            invokeWrite0(msg, promise);
            invokeFlush0();
        } else {
            writeAndFlush(msg, promise);
        }
    }
```

```
...

private void invokeWrite(Object msg, ChannelPromise promise) {
        if (invokeHandler()) {
            invokeWrite0(msg, promise);
        } else {
            write(msg, promise);
        }
    }
```

9.3 抽象编码器处理逻辑 MessageToByteEncoder

将一个对象变成字节并写到socket底层。

io.netty.handler.codec.MessageToByteEncoder#write

```
public void write(ChannelHandlerContext ctx, Object msg, ChannelPromise promise) throws
Exception {
    ByteBuf buf = null;
    try {
        //判断当前encoder处理器是否能处理这个对象
        if (acceptOutboundMessage(msg)) {
            @SuppressWarnings("unchecked")
            I cast = (I) msg;
            buf = allocateBuffer(ctx, cast, preferDirect);
            try {
                //最终会将转化后的对象填充到分配到的buf中
                encode(ctx, cast, buf);
            } finally {
                //释放原始对象
                ReferenceCountUtil.release(cast);
            }

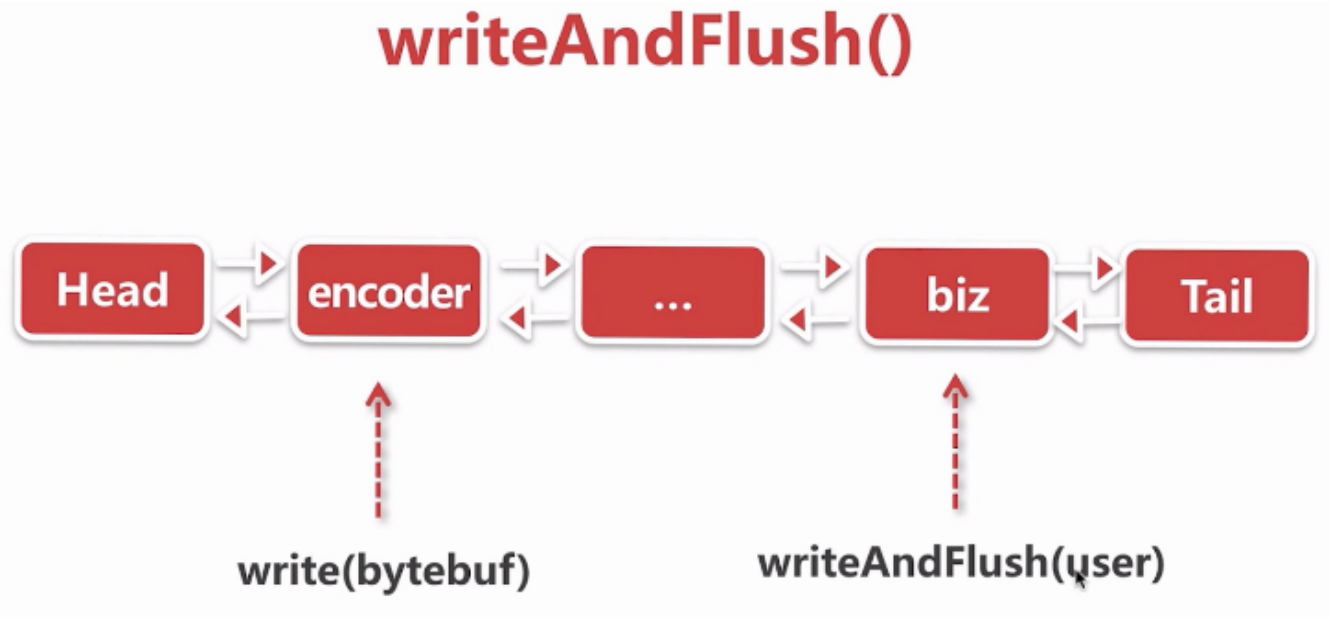
            if (buf.isReadable()) {
```

```
                //传播写好的数据直到Head节点
                ctx.write(buf, promise);
            } else {
                buf.release();
                ctx.write(Unpooled.EMPTY_BUFFER, promise);
            }
            buf = null;
        } else {
            ctx.write(msg, promise);
        }
    } catch (EncoderException e) {
        throw e;
    } catch (Throwable e) {
        throw new EncoderException(e);
    } finally {
        if (buf != null) {
            buf.release();
        }
    }
}

...

protected ByteBuf allocateBuffer(ChannelHandlerContext ctx, @SuppressWarnings("unused") I
msg,boolean preferDirect) throws Exception {
        if (preferDirect) {
            return ctx.alloc().ioBuffer();//分配堆外内存
        } else {
            return ctx.alloc().heapBuffer();//分配堆内内存
        }
    }
```

9.4 写buffer队列



encoder将传进来的user对象转换成bytebuf传递到head节点，最终调用head节点的write方法

io.netty.channel.DefaultChannelPipeline.HeadContext#write

```
public void write(ChannelHandlerContext ctx, Object msg, ChannelPromise promise) throws
Exception {
    unsafe.write(msg, promise);
}
```

io.netty.channel.AbstractChannel.AbstractUnsafe#write

```
public final void write(Object msg, ChannelPromise promise) {
    assertEventLoop();

    ChannelOutboundBuffer outboundBuffer = this.outboundBuffer;
    if (outboundBuffer == null) {
        // If the outboundBuffer is null we know the channel was closed and so
        // need to fail the future right away. If it is not null the handling of the rest
        // will be done in flush0()
        // See https://github.com/netty/netty/issues/2362
        safeSetFailure(promise, WRITE_CLOSED_CHANNEL_EXCEPTION);
        // release message now to prevent resource-leak
        ReferenceCountUtil.release(msg);
        return;
    }

    int size;
    try {
        msg = filterOutboundMessage(msg);
        size = pipeline.estimatorHandle().size(msg);
        if (size < 0) {
            size = 0;
        }
    } catch (Throwable t) {
        safeSetFailure(promise, t);
        ReferenceCountUtil.release(msg);
        return;
    }

    outboundBuffer.addMessage(msg, size, promise);
}
```

write-写buffer队列

- direct化ByteBuf
    - 将非堆外内存转化为堆外内存（零拷贝）

  io.netty.channel.nio.AbstractNioByteChannel#filterOutboundMessage

  ```
  protected final Object filterOutboundMessage(Object msg) {
      if (msg instanceof ByteBuf) {
          ByteBuf buf = (ByteBuf) msg;
          if (buf.isDirect()) {
              return msg;
  ```

```
        }
        return newDirectBuffer(buf);
    }

    if (msg instanceof FileRegion) {
        return msg;
    }
    throw new UnsupportedOperationException(
            "unsupported message type: " + StringUtil.simpleClassName(msg) +
EXPECTED_TYPES);
}
```

- 插入写队列（写缓冲区 outBoundBuffer）

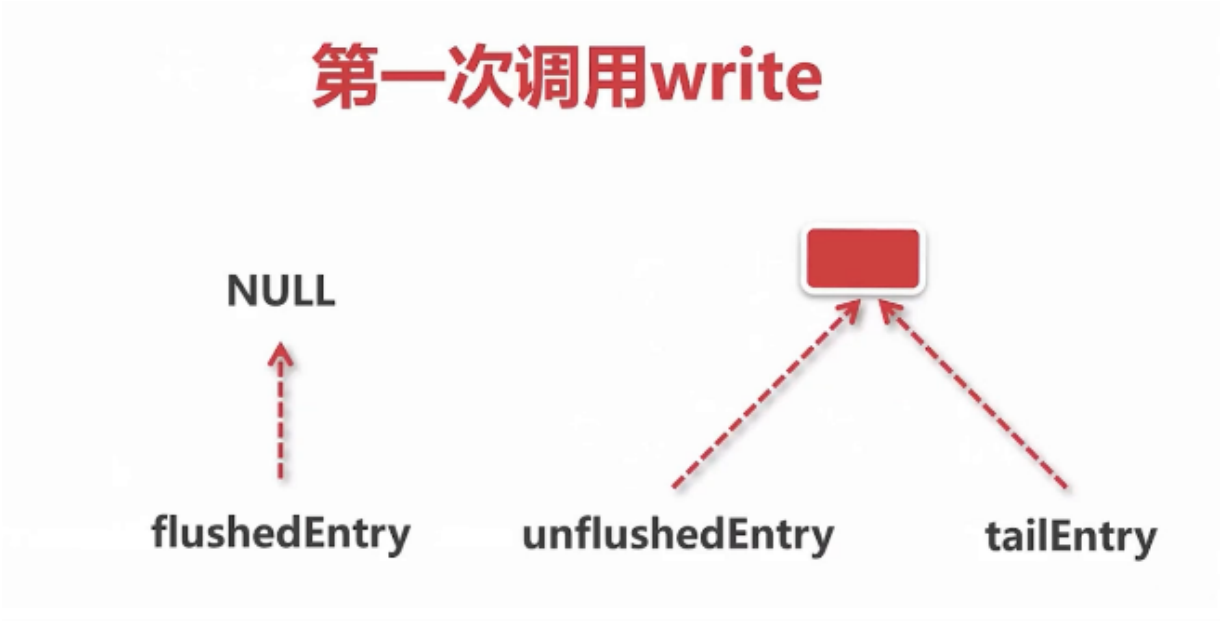
  io.netty.channel.ChannelOutboundBuffer#addMessage

```
//三个指针
// Entry(flushedEntry) --> ... Entry(unflushedEntry) --> ... Entry(tailEntry)
//
// The Entry that is the first in the linked-list structure that was flushed
private Entry flushedEntry;
// The Entry which is the first unflushed in the linked-list structure
private Entry unflushedEntry;
// The Entry which represents the tail of the buffer
private Entry tailEntry;

......

public void addMessage(Object msg, int size, ChannelPromise promise) {
    Entry entry = Entry.newInstance(msg, size, total(msg), promise);
    if (tailEntry == null) {
        flushedEntry = null;
        tailEntry = entry;
    } else {
        Entry tail = tailEntry;
        tail.next = entry;
        tailEntry = entry;
    }
    if (unflushedEntry == null) {
        unflushedEntry = entry;
    }

    // increment pending bytes after adding message to the unflushed arrays.
    // See https://github.com/netty/netty/issues/1619
    incrementPendingOutboundBytes(size, false);
}
```



- 设置写状态
    - 若写缓冲区中的数据 > 默认的高水位 64k 就设置当前的channel为不可写状态

io.netty.channel.ChannelOutboundBuffer#incrementPendingOutboundBytes(long, boolean)

```
private void incrementPendingOutboundBytes(long size, boolean invokeLater) {
    if (size == 0) {
        return;
    }

    long newWriteBufferSize = TOTAL_PENDING_SIZE_UPDATER.addAndGet(this, size);
    if (newWriteBufferSize > channel.config().getWriteBufferHighWaterMark()) {
        setUnwritable(invokeLater);
    }
}

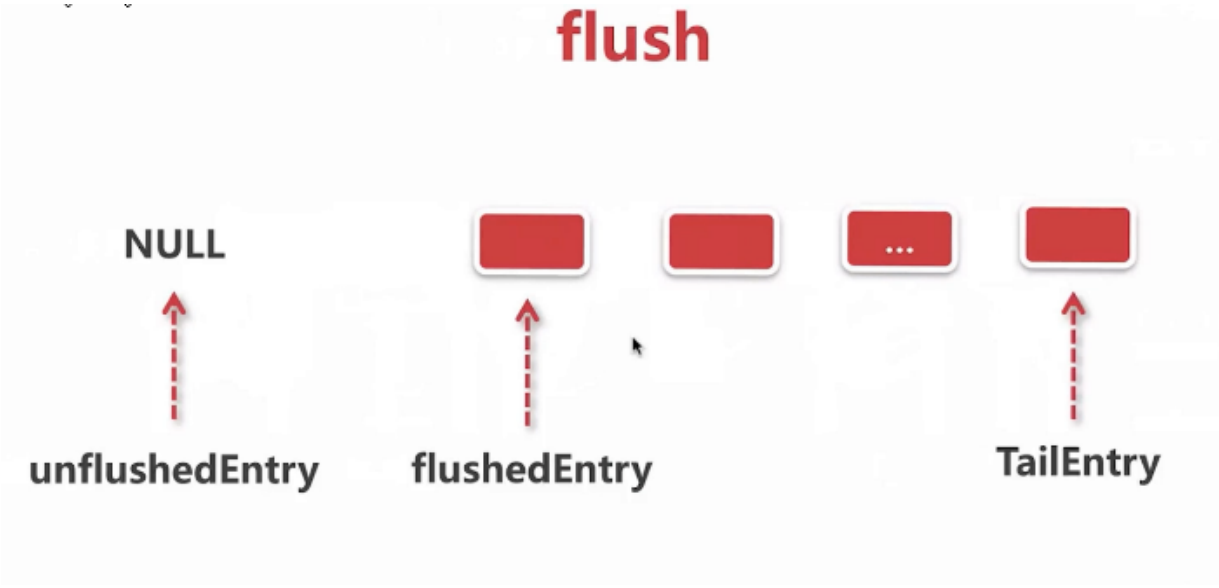
...

// 自旋 + CAS
private void setUnwritable(boolean invokeLater) {
        for (;;) {
            final int oldValue = unwritable;
            final int newValue = oldValue | 1;
            if (UNWRITABLE_UPDATER.compareAndSet(this, oldValue, newValue)) {
                if (oldValue == 0 && newValue != 0) {
                    fireChannelWritabilityChanged(invokeLater);
                }
                break;
            }
        }
    }
```

9.5 刷新buffer队列

flush - 刷新buffer队列 将缓存区中的数据写入socket通道

- 添加刷新标志并设置写状态
    - 移动三个指针
    - 若写缓冲区中的数据 < 默认的低水位 32k 就设置当前的channel为可写状态



- 遍历buffer队列，过滤ByteBuf

- 调用jdk底层的API进行自选写

io.netty.channel.DefaultChannelPipeline.HeadContext#flush

```
public void flush(ChannelHandlerContext ctx) throws Exception {
    unsafe.flush();
}
```

io.netty.channel.AbstractChannel.AbstractUnsafe#flush

```
public final void flush() {
    assertEventLoop();

    ChannelOutboundBuffer outboundBuffer = this.outboundBuffer;
    if (outboundBuffer == null) {
        return;
    }
    outboundBuffer.addFlush();
    flush0();
}
```

io.netty.channel.ChannelOutboundBuffer#decrementPendingOutboundBytes(long, boolean, boolean)

```
private void decrementPendingOutboundBytes(long size, boolean invokeLater, boolean
notifyWritability) {
    if (size == 0) {
        return;
    }
    long newWriteBufferSize = TOTAL_PENDING_SIZE_UPDATER.addAndGet(this, -size);
    if (notifyWritability && newWriteBufferSize <
channel.config().getWriteBufferLowWaterMark()) {
        setWritable(invokeLater);
    }
}
```

io.netty.channel.DefaultChannelConfig#writeBufferWaterMark

```
private volatile WriteBufferWaterMark writeBufferWaterMark = WriteBufferWaterMark.DEFAULT;
```

io.netty.channel.WriteBufferWaterMark

```
public final class WriteBufferWaterMark {

    private static final int DEFAULT_LOW_WATER_MARK = 32 * 1024;
    private static final int DEFAULT_HIGH_WATER_MARK = 64 * 1024;

    public static final WriteBufferWaterMark DEFAULT =
            new WriteBufferWaterMark(DEFAULT_LOW_WATER_MARK, DEFAULT_HIGH_WATER_MARK,
false);

    private final int low;
    private final int high;
    ...
}
```

io.netty.channel.nio.AbstractNioByteChannel#doWrite

```
protected void doWrite(ChannelOutboundBuffer in) throws Exception {
    int writeSpinCount = -1;

    boolean setOpWrite = false;
    for (;;) {
        Object msg = in.current();
        if (msg == null) {
            // Wrote all messages.
            clearOpWrite();
            // Directly return here so incompleteWrite(...) is not called.
            return;
        }

        if (msg instanceof ByteBuf) {
            ByteBuf buf = (ByteBuf) msg;
            int readableBytes = buf.readableBytes();
            if (readableBytes == 0) {
                in.remove();
                continue;
            }

            boolean done = false;
            long flushedAmount = 0;
            if (writeSpinCount == -1) {
                // 并发编程中使用自旋可以提高内存使用率和吞吐量
                writeSpinCount = config().getWriteSpinCount();
            }
            for (int i = writeSpinCount - 1; i >= 0; i --) {
                //将buf写到socket
                int localFlushedAmount = doWriteBytes(buf);
                if (localFlushedAmount == 0) {
                    setOpWrite = true;
                    break;
                }
```

```
                flushedAmount += localFlushedAmount;
                if (!buf.isReadable()) {
                    done = true;
                    break;
                }
            }

            in.progress(flushedAmount);

            if (done) {
                in.remove();
            } else {
                // Break the loop and so incompleteWrite(...) is called.
                break;
            }
        } else if (msg instanceof FileRegion) {//认为是从磁盘读到socket
            FileRegion region = (FileRegion) msg;
            boolean done = region.transferred() >= region.count();
            ...
        } else {
            // Should not reach here.
            throw new Error();
        }
    }
    incompleteWrite(setOpWrite);
}
```

io.netty.channel.ChannelConfig#getWriteSpinCount

```
/**
    自旋提高写的吞吐量，默认自旋16次
 * Returns the maximum loop count for a write operation until
 * {@link WritableByteChannel#write(ByteBuffer)} returns a non-zero value.
 * It is similar to what a spin lock is used for in concurrency programming.
 * It improves memory utilization and write throughput depending on
 * the platform that JVM runs on.  The default value is {@code 16}.
 */
int getWriteSpinCount();
```

io.netty.channel.socket.nio.NioSocketChannel#doWriteBytes

```
protected int doWriteBytes(ByteBuf buf) throws Exception {
    final int expectedWrittenBytes = buf.readableBytes();
    return buf.readBytes(javaChannel(), expectedWrittenBytes);
}
```

io.netty.buffer.PooledDirectByteBuf#readBytes(java.nio.channels.GatheringByteChannel, int)

```
public int readBytes(GatheringByteChannel out, int length) throws IOException {
    checkReadableBytes(length);
    int readBytes = getBytes(readerIndex, out, length, true);
    readerIndex += readBytes;
    return readBytes;
}
```

io.netty.buffer.PooledDirectByteBuf#getBytes(int, java.nio.channels.GatheringByteChannel, int, boolean)

```
// GatheringByteChannel 是 JDK底层的
private int getBytes(int index, GatheringByteChannel out, int length, boolean internal)
throws IOException {
    checkIndex(index, length);
    if (length == 0) {
        return 0;
    }

    //JDK相关的ByteBUffer 将netty自定以的byteBuf塞到JDK的ByteBUffer
    ByteBuffer tmpBuf;
    if (internal) {
        tmpBuf = internalNioBuffer();
    } else {
        tmpBuf = memory.duplicate();
    }
    index = idx(index);
    tmpBuf.clear().position(index).limit(index + length);
    // 调用JDK底层的write方法，将tmpBuf写到socket通道中，并返回写的字节数
    return out.write(tmpBuf);
}
```

9.6 netty编码总结