Advanced Java™ NIO Technology-Based Applications Using the Grizzly Framework

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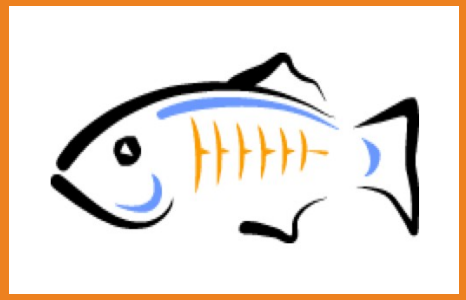
TS-4883



Java

Sun microsystems

Learn how easy it can be to write scalable client-server applications with the Grizzly Framework.

GOAL

Agenda

- What is the Project Grizzly
- The Server Components
- The Client Components
- Asynchronous Read and Write Queue
- Synchronous Read and Write using Temporary Selectors
- Persisting your data using ThreadAttachment
- HTTP Modules
- NIO.2 Support
- Summary

What is Project Grizzly

- Open Source Project on java.net, https://grizzly.dev.java.net
- Open Sourced under CDDL/LGPL license.
- Very open community policy.
  - All project communications are done on Grizzly mailing list. No internal, off mailing list conversations.
  - Project meetings open to anyone (public conference call).
- Project decisions are made by project member votes.
- Sun and non Sun commiters.

What is Project Grizzly

- Uses Java NIO primitives and hides the complexity programming with Java NIO.
- Easy-to-use high performance APIs for TCP, UDP and SSL communications.
- Brings non-blocking sockets to the protocol processing layer.
- Utilizes high performance buffers and buffer management.
- Choice of several different high performance thread pools.
- Ship with an HTTP module which is really easy to extend.
- **Use the Framework, but STILL have a way to control the IO layer.**

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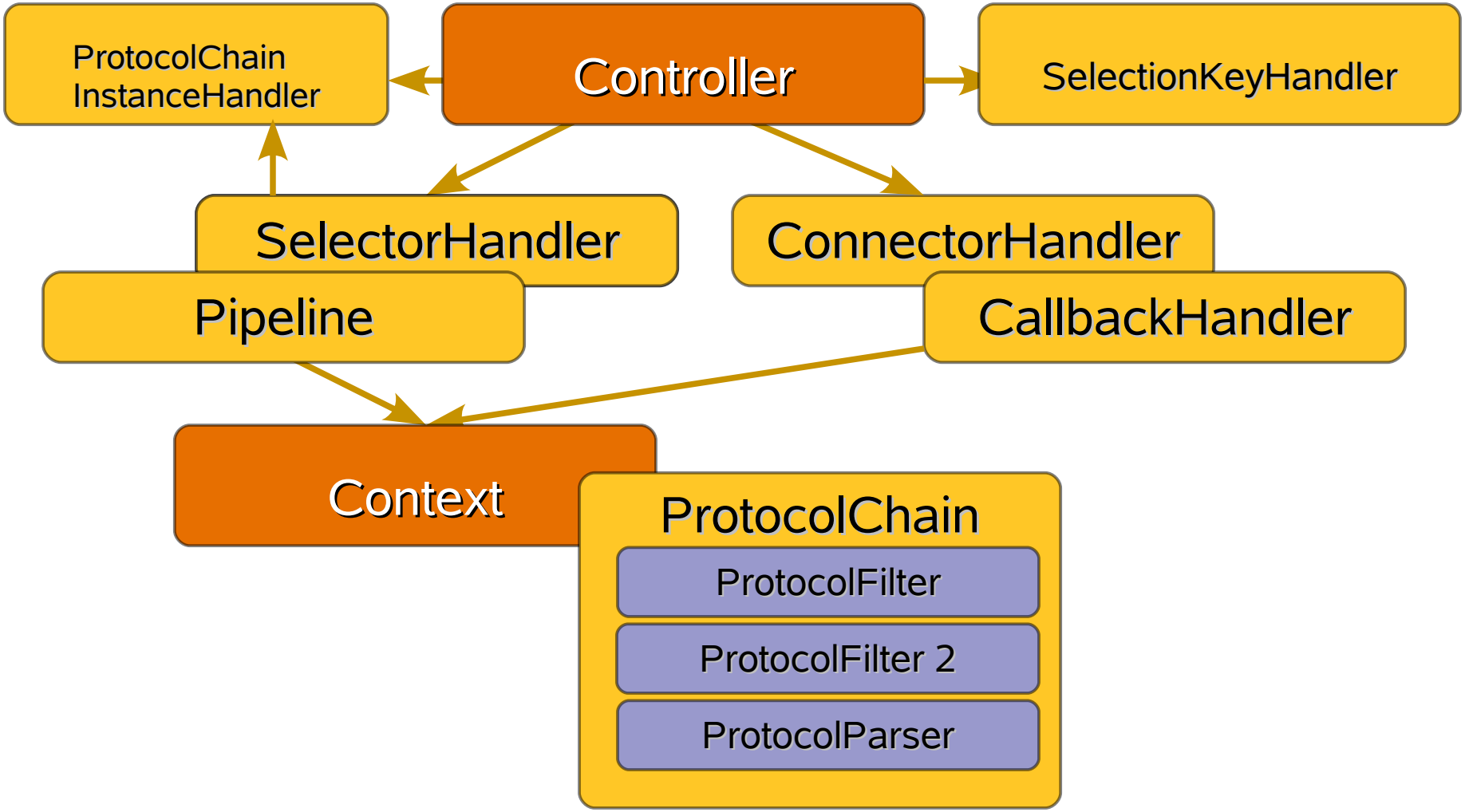
Example 1 – Server, how easy it is

- The Grizzly Framework bundles default implementation for TCP, UDP and TLS/SSL transports.
- Every supported transport SelectorHandler should be added to a Controller
- By default, you can use TCPSelectorHandler, UDPSelectorHandler and TLSSelectorHandler.
- You can also create your own by implementing the SelectorHandler interface.
- In Grizzly, EVERYTHING is customizable. If the default isn't doing what you need, customize it!

Grizzly's Monster face



Example: Simple log server over TCP

```
Controller controller = new Controller();
controller.setProtocolChainInstanceHandler(new
   DefaultProtocolChainInstanceHandler() {

    ProtocolChain protocolChain;
    // Stateless ProtocolChain
    public ProtocolChain poll() {

      if(protocolChain == null) {
         protocolChain = new DefaultProtocolChain();
         protocolChain.addFilter(new ReadFilter());
         protocolChain.addFilter(new LogFilter());
      }

      return protocolChain;
});
```

Example: Supporting TCP and UDP

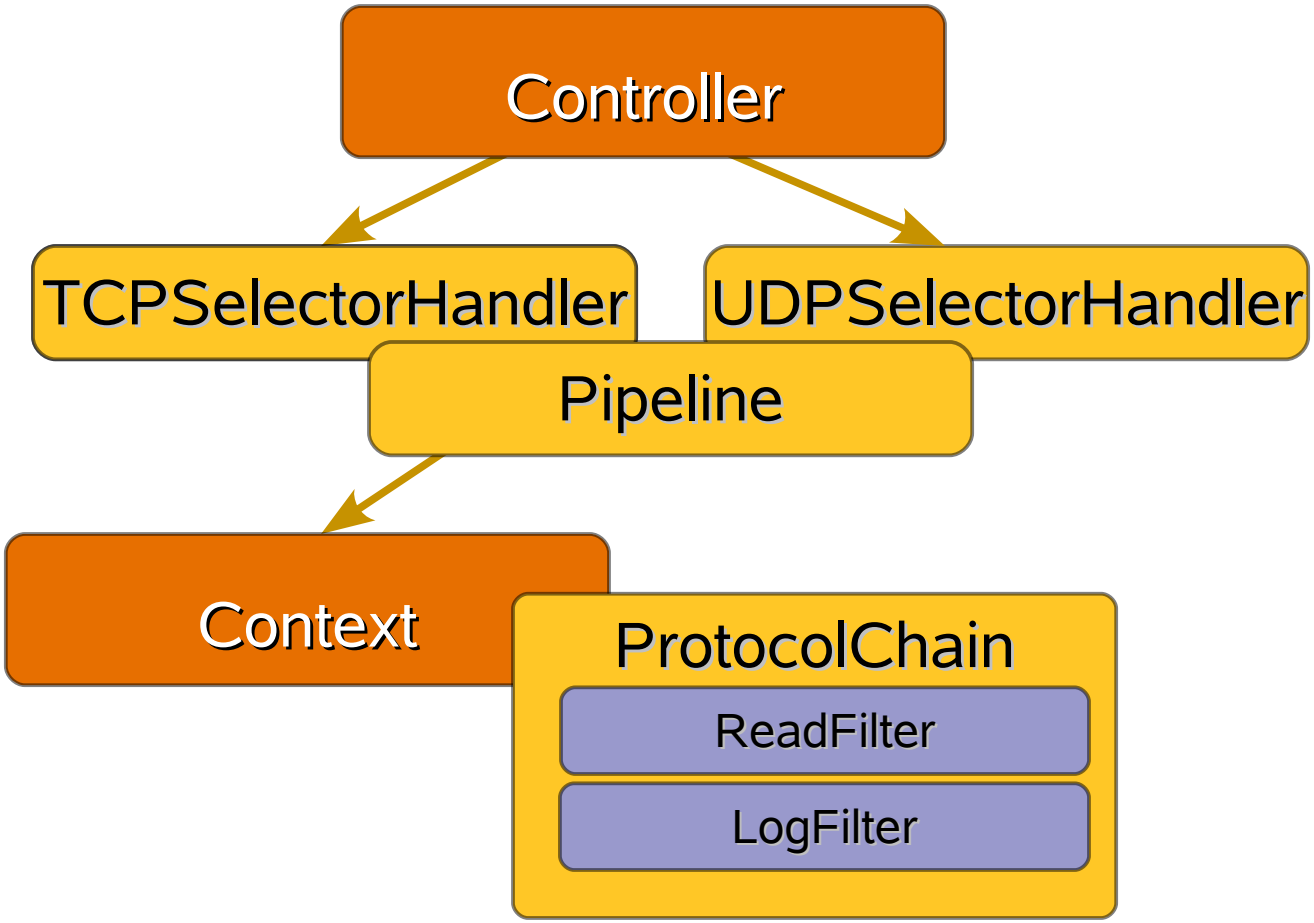
```
Controller controller = new Controller();

controller.addSelectorHandler(new TCPSelectorHandler());
controller.addSelectorHandler(new UDPSelectorHandler());
controller.setProtocolChainInstanceHandler(new
   DefaultProtocolChainInstanceHandler() {

    ProtocolChain protocolChain;
    // Stateless ProtocolChain
    public ProtocolChain poll() {

      if(protocolChain == null) {
         protocolChain = new DefaultProtocolChain();
         protocolChain.addFilter(new ReadFilter());
         protocolChain.addFilter(new LogFilter());
      }

      return protocolChain;
});
```


Controller
TCPSelectorHandler
UDPSelectorHandler
Pipeline
Context
ProtocolChain
ReadFilter
LogFilter

Example: Why not TLS?

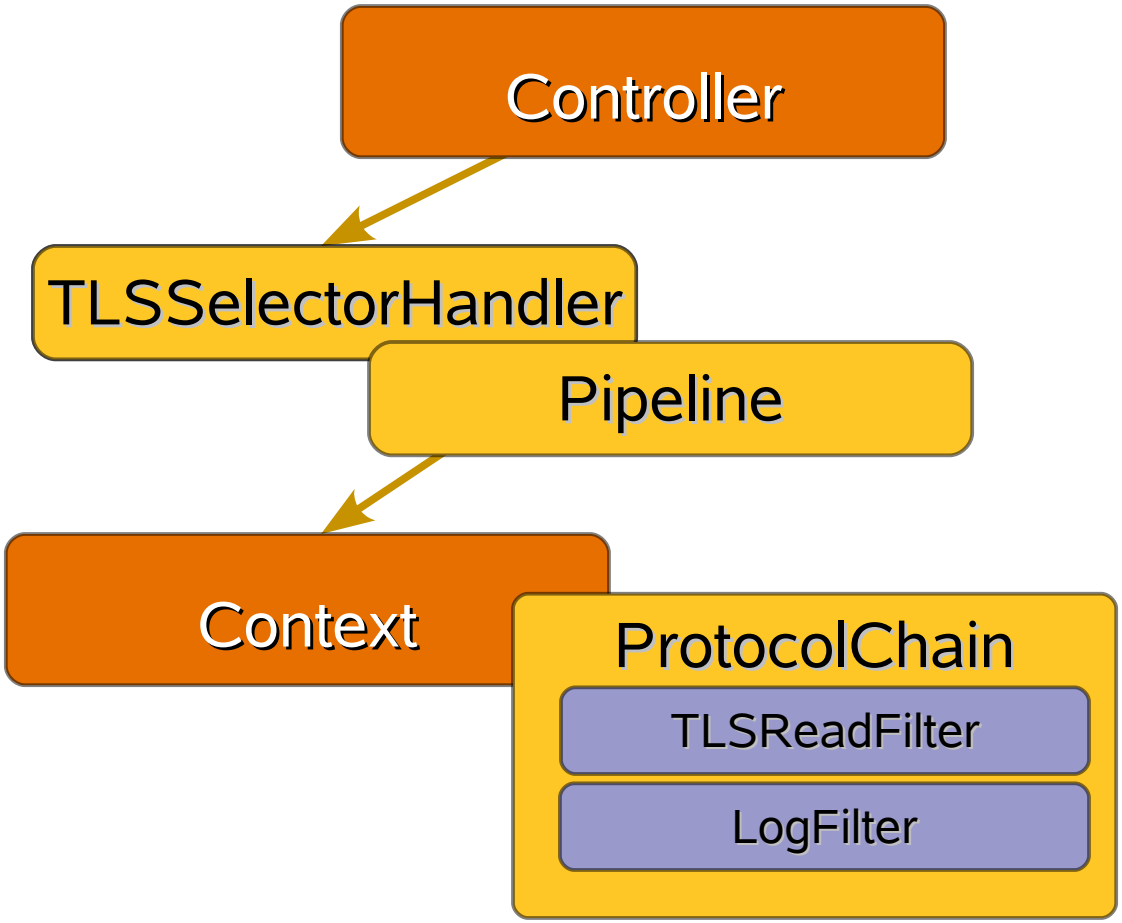
```
Controller controller = new Controller();

controller.addSelectorHandler(new TLSSelectorHandler());
controller.setProtocolChainInstanceHandler(new
   DefaultProtocolChainInstanceHandler() {

    ProtocolChain protocolChain;
    // Stateless ProtocolChain
    public ProtocolChain poll() {

      if(protocolChain == null) {
         protocolChain = new DefaultProtocolChain();
         protocolChain.addFilter(new TLSReadFilter();
         protocolChain.addFilter(new LogFilter());
      }

      return protocolChain;
});
```


Controller
TLSSelectorHandler
Pipeline
Context
ProtocolChain
TLSReadFilter
LogFilter

Controller

- The main entry point when working with Grizzly.
- A Controller is composed of
  - SelectorHandler
  - ConnectorHandler
  - SelectionKeyHandler
  - ProtocolChainInstanceHandler
  - ProtocolChain
  - Pipeline
- By default, all these interfaces have ready to use implementations.
- All of these components are customizable using the Grizzly Framework

SelectorHandler (optional)

- A SelectorHandler handles all java.nio.channels.Selector operations.
- The logic for processing of SelectionKey interest(OP_READ, OP_WRITE, etc) is usually defined using an instance of SelectorHandler
- Ex: TCPSelectorHandler, UDPSelectorHandler

```
public void preSelect(Context ctx)
      throws IOException;

public Set<SelectionKey> select(Context ctx)
      throws IOException;

public void postSelect(Context ctx)
      throws IOException;
```

SelectionKeyHandler (optional)

- A SelectionKeyHandler used to handle the life-cycle of a SelectionKey. This object is responsible of canceling, registering or closing (timing out) SelectionKey(s).
- You can have one SelectionKey per SelectorHandler, or globally shared amongst them.

```
public void register(Iterator<SelectionKey> it, int
selectionKeyOps);

public void expire(Iterator<SelectionKey> it);

public void cancel(SelectionKey key);

public void close(SelectionKey key);
```

ProtocolFilter

- A ProtocolFilter encapsulates a unit of processing work to be performed, whose purpose is to examine and/or modify the state of a transaction that is represented by a Context.
- Most Grizzly based application only have to write an implementation of one ProtocolFilter.
- Individual ProtocolFilters can be assembled into a ProtocolChain.
- The only classes you might have to write!

```
public boolean execute(Context ctx) throws
IOException;

public boolean postExecute(Context ctx) throws
IOException;
```

ProtocolParser

- A specialized ProtocolFilter that knows how to parse bytes into protocol unit of data.
- Simply protocol implementation in Grizzly. Split protocol parsing state into steps:
  - start processing a buffer
  - enumerate the message in the buffer
  - and end processing the buffer.
- The buffer can contain 0 or more complete messages, and it's up to the protocol parser to make sense of that.

```
public T getNextMessage();

public boolean hasNextMessage();

public void startBuffer(ByteBuffer bb);

public boolean releaseBuffer();
```

ProtocolChain (optional)

- A ProtocolChain implements the “Chain of Responsibility” pattern (for more info take a look at the classic “Gang of Four” design patterns book).
- The ProtocolChain API models a computation as a series of “protocol filters”, that can be combined into a “protocol chain”.

```
public boolean addFilter(ProtocolFilter pf);

public boolean removeFilter(ProtocolFilter pf);

public void execute(Context context) throws Exception;
```

ProtocolChainInstanceHandler (optional)

- A ProtocolChainInstanceHandler is where one or several ProtocolChains are created and cached.
- A ProtocolChainInstanceHandler decides if a stateless or stateful ProtocolChain needs to be created:
  - Stateless: One ProtocolChain instance shared amongst Threads.
  - Statefull: One ProtocolChain instance per Thread

```
public ProtocolChain poll();

public boolean offer(ProtocolChain pc);
```

Pipeline (optional)

- An interface is used as a wrapper around any kind of thread pool.
- The best performing implementation is the default configured Pipeline.
- Can have one Pipeline per SelectorHandler or a shared one amongst them.

```
public void execute(E task) throws
                                    PipelineFullException;

public E waitForIoTask() ;
```

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- The Client Components
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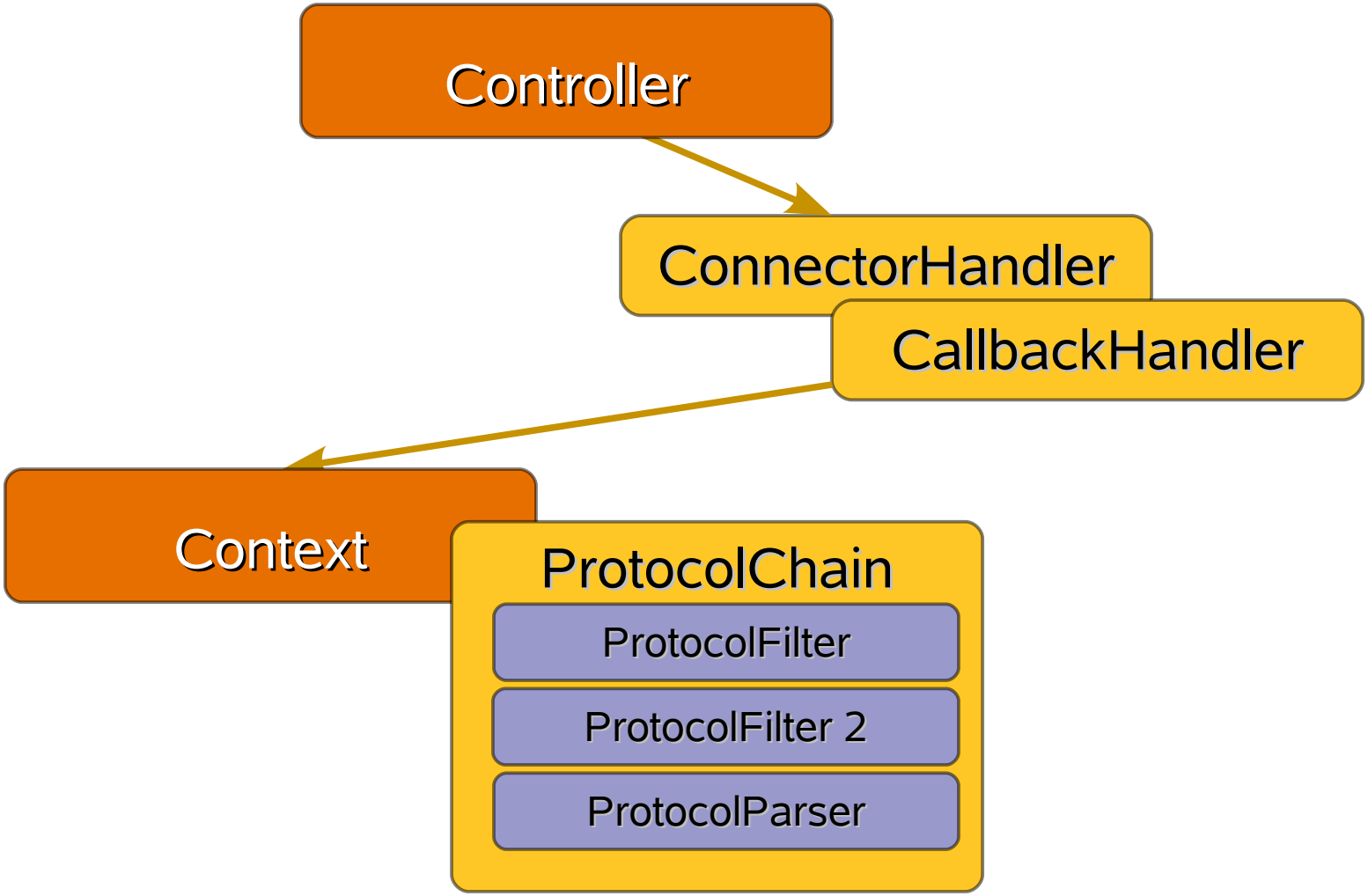
Example 2 – Client: synchronous mode

```
Controller ctrl = new Controller();
ctrl.addSelectorHandler(new TCPSelectorHandler(true));
startGrizzly(ctrl);

ConnectorHandler connection =
            ctrl.acquireConnectorHandler(Protocol.TCP);

connection.connect(new InetSocketAddress(host, port));
connection.write(outputByteBuffer, true);
connection.read(inputByteBuffer, true);
connection.close();
ctrl.releaseConnectorHandler(connection);
```

Grizzly's Client Monster face



Example 2 – Client: asynchronous mode

```
Controller ctrl = new Controller();
ctrl.addSelectorHandler(new TCPSelectorHandler(true));
startGrizzly(ctrl);
ConnectorHandler connection =
            ctrl.acquireConnectorHandler(Protocol.TCP);
connection.connect(new InetSocketAddress(host, port),
            new CustomCallbackHandler(connection));
connection.write(giantByteBuffer, false);


// continue, while ByteBuffer will be writen
asynchronously
```

Example 2 – Client: asynchronous mode (cont.)

```
public class CustomCallbackHandler implements
                                CallbackHandler<Context> {
   private ConnectorHandler connection;

   CustomCallbackHandler(ConnectorHandler connection){
       this.connection = connection;
   }

   public void onWrite(IOEvent<Context> ioEvent) {
       connection.write(giantByteBuffer, false);
       if (!giantByteBuffer.hasRemaining()) {
          notifyAsyncWriteCompleted();
       }
   }

// Skip other CallbackHandler methods implementation...
}
```

ConnectorHandler

- Client side connection unit, which implements basic I/O functionality: connect, read, write, close.
- Provides possibility of working in both synchronous and asynchronous modes (e.g. blocking or non blocking read/write).
- Asynchronous operation execution could be controlled by CallbackHandler with user custom code, or automatically by framework, using asynchronous read and write queues.
- Grizzly Framework contains default TCP,TLS UDP ConnectorHandler implementations.

CallbackHandler

- Handles client side asynchronous I/O operations: connect, read, write. Corresponding CallbackHandler method will be called, when NIO channel is ready to perform the operation.
- Asynchronous events could be either processed inside CallbackHandler or propagated to a ProtocolChain.
- When processing asynchronous event inside CallbackHandler, be careful with SelectionKey interests registration.

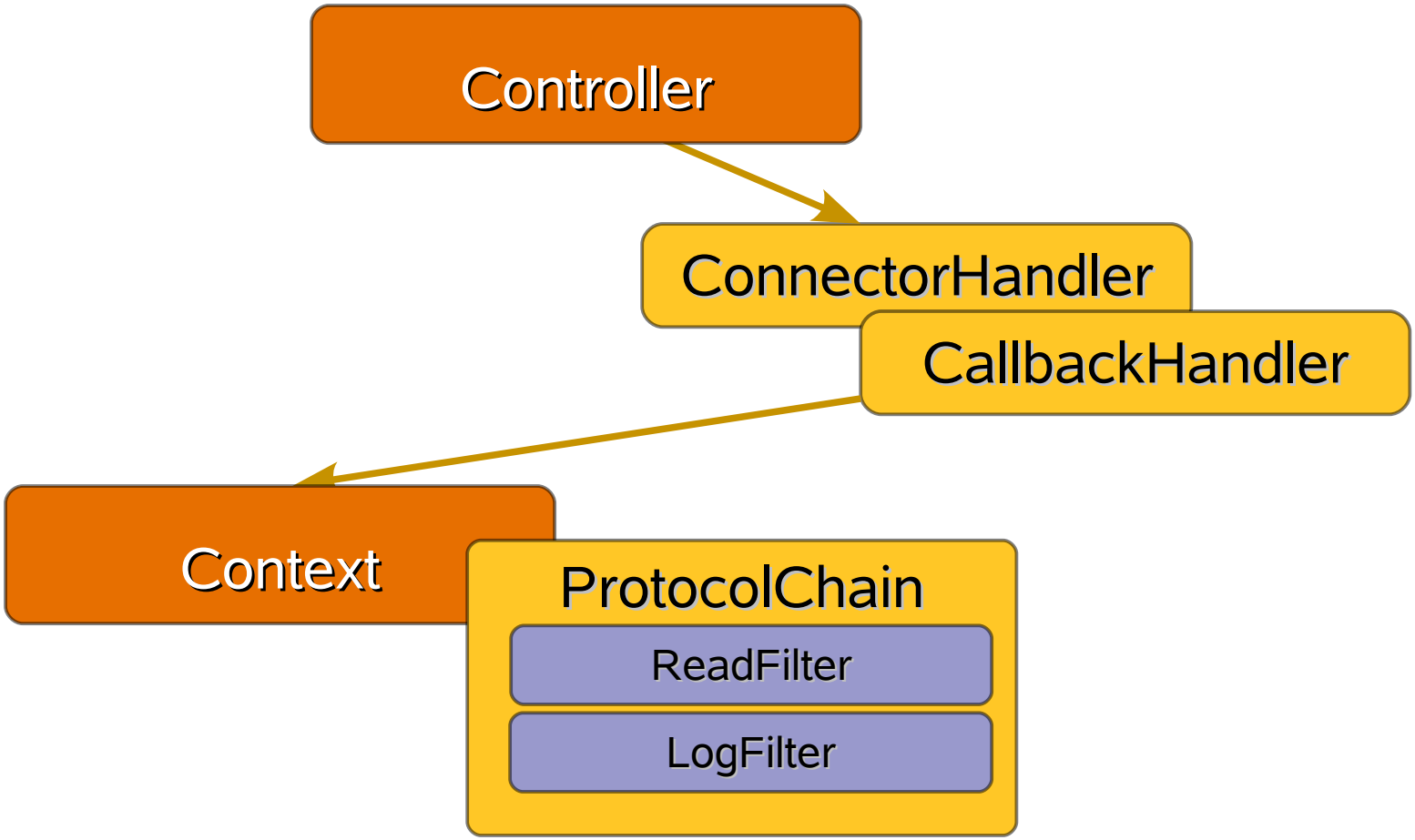
```
public void onConnect(IOEvent<E> ioEvent);

public void onRead(IOEvent<E> ioEvent);

public void onWrite(IOEvent<E> ioEvent);
```

Client and server side logic unification

- There are use cases, where both client and server sides should process requests similar way, for example CORBA or SIP.
- CallbackHandler are able to redirect a request processing to a ProtocolChain, so high level protocol logic, which is implemented in ProtocolChain filters will be accessible from client side API too.


Controller
ConnectorHandler
CallbackHandler
Context
ProtocolChain
ReadFilter
LogFilter

Example 3 – Client and server side logic unification

```
public class CallbackHandlerToProtocolChain implements
                                    CallbackHandler<Context> {
    public void onRead(IOEvent<Context> context) {
        Context context = ioEvent.attachment();
        context.getProtocolChain().execute(context);
    }

// Skip other CallbackHandler methods implementation...
}
```

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Asynchronous write queue

- Provides user the easy way for sending data asynchronously and be notified, when operation will be either successfully completed or interrupted due to I/O error.
- Asynchronous write queue is thread safe. Data from different buffers will never be intermixed.
- Asynchronous write queue processors provide easy and pluggable way to compress, encrypt output data just before it will be sent over NIO channel.
- Grizzly Framework has default asynchronous write queue implementation for UDP and TCP protocols.

Asynchronous read queue

- Provides user the easy way for receiving data asynchronously and be notified, when operation will be either successfully completed or interrupted due to I/O error.
- Asynchronous read queue is thread safe. Next buffer will start to fill up only after current one will be completed.
- Asynchronous read queue processors provide easy and pluggable way to decompress, decrypt input data just after it was read from NIO channel.

Asynchronous read queue (cont.)

- Asynchronous read conditions provide user possibility to set custom “read complete” condition. By default asynchronous read will consider completed, when input ByteBuffer will become full.
- Grizzly Framework has default asynchronous read queue implementation for UDP and TCP protocols.

Example 6 – Asynchronous queue: write

```
class AsyncQueueEchoFilter implements ProtocolFilter {
   public boolean execute(Context ctx)
                                        throws IOException {
      ByteBuffer buffer = getByteBuffer(ctx);
      // we pass null for callback notificator and
      // data processor. Last true parameter means buffer
      // will be cloned before added to the queue
      ctx.getAsyncQueueWritable().writeToAsyncQueue(
                                    buffer, null, null, true);
   }

    public boolean postExecute(Context ctx)
                                        throws IOException {
        return true;
    }
}
```

Example 6 – Asynchronous queue: read

```
ConnectorHandler connection =
            ctrl.acquireConnectorHandler(Protocol.TCP);
connection.connect(new InetSocketAddress(host, port));

// request notification, when byte buffer will be full
AsyncReadCallbackHandler notificationHandler =
   new CustomAsyncReadCallbackHandler();
connection.readFromAsyncQueue(bigByteBuffer,
   notifiicationHandler);
```

Example 6 – Asynchronous queue: read (cont.)

```
class CustomAsyncReadCallbackHandler implements
                                AsyncReadCallbackHandler {

   public void onReadCompleted(SelectionKey key,
      SocketAddress srcAddress, ByteBuffer buffer) {
      processReadData(buffer);
   }

   public void onIOException(IOException ioException,
       ...
   }
}
```

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Synchronous Read and Write

- There is some situations where registering a Channel on more than one Selector improve performance:
  - Instead of registering a SelectionKey using the Selector used by the acceptor thread (the Selector than handled the OP_ACCEPT), get a Selector from a pool and try to read/write more bytes using it.

```
readSelector = SelectorFactory.getSelector();
tmpKey = socketChannel.register
                (readSelector,SelectionKey.OP_READ)
tmpKey.interestOps(tmpKey.interestOps() |
   SelectionKey.OP_READ);
int code = readSelector.select(readTimeout);
tmpKey.interestOps(tmpKey.interestOps() &
                        (~SelectionKey.OP_READ));
while (count > 0){
     count = socketChannel.read(byteBuffer);
 }
```

Synchronous Read and Write (Con't)

- Grizzly offers two utility classes for supporting synchronous read and write:
  - com.sun.grizzly.util.InputReader

```
{
    InputReader syncReader = new InputReader();
    // Block at most 5 seconds.
    syncReader.read(bb,5,TimeUnits.SECONDS);
}
```

  - com.sun.grizzly.util.OutputWriter

```
{
    // Block at most 5 seconds.
    OutputWriter.write(bb,5,TimeUnits.SECONDS);
}
```

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ThreadAttachment

- Between OP_READ and OP_WRITE, some protocol needs to keep some states (remaining bytes inside a byte buffer, attributes, etc.).
- In Grizzly, the default is to associate one Byte Buffer per Thread. That means a byte buffer cannot be cached as its Thread can always be re-used for another transaction.
- To persist the byte buffer amongs transactions, a Thread Attachment can be used:

```
{
    WorkerThread wt =
        (WorkerThread)Thread.currentThread();
    ThreadAttachment = wt.detach();
}
```

ThreadAttachment (Con't)

- What happens is internally, all attributes associated with the WorkerThread are 'detached', and new instance recreated
  - Warning: A new ByteBuffer will be created!!
- The ThreadAttachment can be attached to a SelectionKey, and next time an OP_READ/OP_WRITE happens, you are guarantee the value will be re-used.

```
{
    ta.setAttribute(keepAliveCount,10);
    ctx.getSelectionKey().attach(ta);
    ...
    TheadAttachment ta = (ThreadAttachment)
        ctx.getSelectionKey().attachment();
    int keepAliveCount = (int)ta.getAttibute();
}
```

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HTTP modules

- The Grizzly Framework also have an HTTP framework that can be used to build Web Server
  - This is what GlassFish™ v1|2|3 build on top of.
  - More specialized modules are also available like **Comet** (Async HTTP).
- Simple interface to allow customization of the HTTP Protocol
  - GrizzlyRequest: A utility class to manipulate the HTTP protocol request.
  - GrizzlyResponse: A utility class to manipulate the HTTP protocol response.
  - GrizzlyAdapter: A utility class to manipulate the HTTP request/response object.

HTTP protocol module (Con't)

```
public class FileAdapter extends GrizzlyAdapter{
    public void service(GrizzlyRequest req,
                        GrizzlyResponse res){
        String fileUri = req.getRequestURI();

        FileChannel file = ....;
        fileChannel.transferTo(...);

        res.flush();
        res.close();
    }
}
```

Example: Jersey (jersey.dev.java.net).

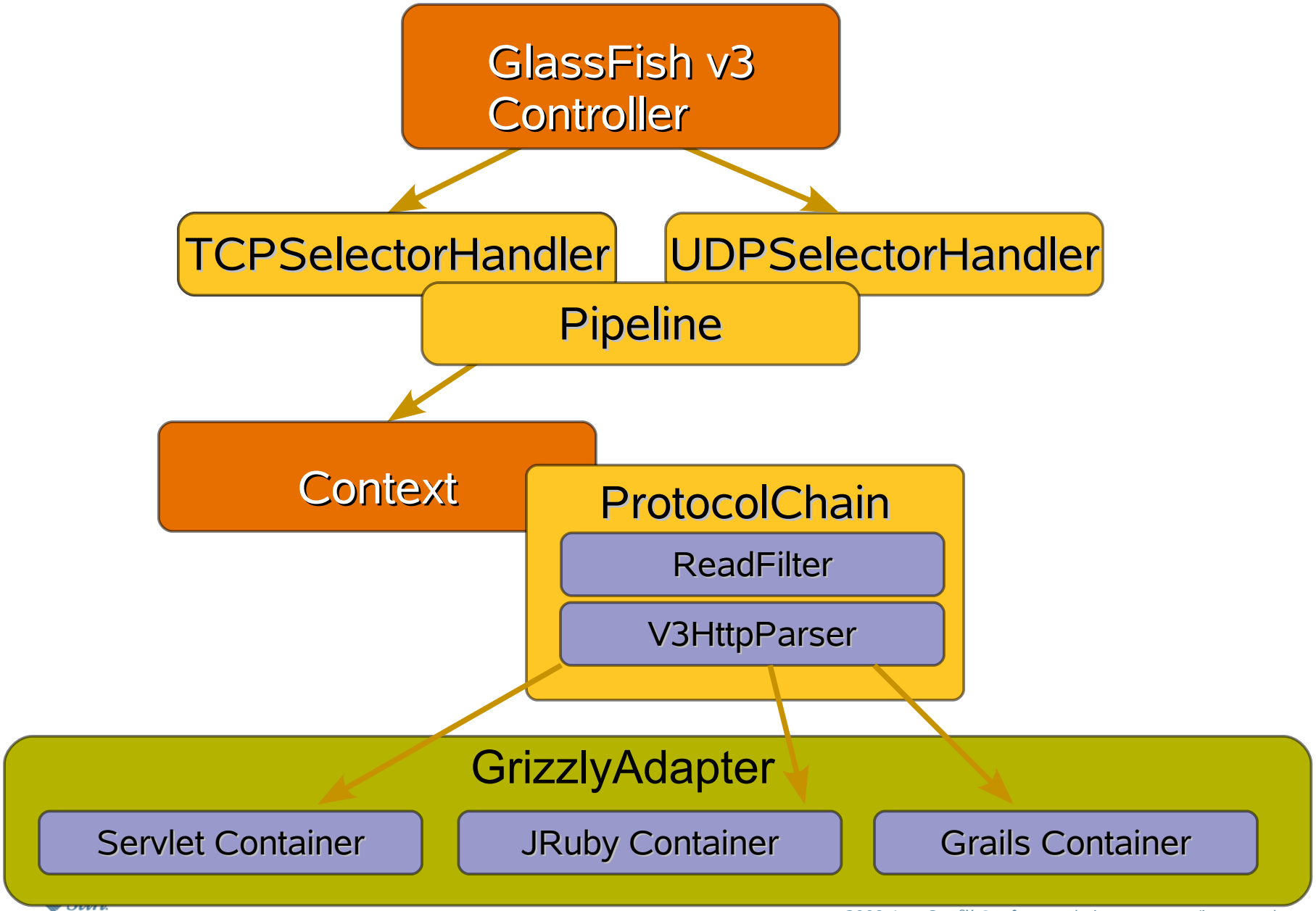
- Jersey is the open source JAX-RS (Java Specification Request (JSR) 311) Reference Implementation for building RESTful Web services.
- By default, Jersey ship with support for Grizzly HTTP WebServer:
  - Implement the GrizzlyAdapter interface, use the GrizzlyRequest and Response object to handle the http protocol.
- In less than 20 minutes, Jersey was running with Grizzly!

Example: Jersey (jersey.dev.java.net).

```
public void service(GrizzlyRequest request,
                    GrizzlyResponse response) {
  try {
    requestAdaptor = new GrizzlyRequestAdaptor(
            application.getMessageBodyContext(),request);

    responseAdaptor =
             new GrizzlyResponseAdaptor(response,
                    application.getMessageBodyContext(),
                    requestAdaptor);

    application.handleRequest(requestAdaptor,
                    responseAdaptor);
```

Example: Jersey (Con't).

```
protected void commitStatusAndHeaders() throws IOException {
    response.setStatus(this.getStatus());

    for (Map.Entry<String, List<Object>> e :
                                    this.getHttpHeaders().entrySet()) {
        String key = e.getKey();
        for (Object value: e.getValue()) {
            response.addHeader(key,value.toString());
        }
    }

    String contentType = response.getHeader("Content-Type");
    if (contentType != null) {
        response.setContentType(contentType);
    }
}
```


GlassFish v3
Controller
TCPSelectorHandler
UDPSelectorHandler
Pipeline
Context
ProtocolChain
ReadFilter
V3HttpParser
GrizzlyAdapter
Servlet Container
JRuby Container
Grails Container

GlassFish v3 Demo

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NIO.2: Asynchronous I/O (JSR-203)

- NIO.2 is:
  - An API for asynchronous (as opposed to polled, non-blocking) I/O operations on both sockets and files.
  - The completion of the socket-channel functionality defined in JSR-51, including the addition of support for binding, option configuration, and multicast datagrams.
- Starting in Grizzly 1.8.0, Asynchronous I/O is supported if you are running JDK version 7.
- You can easily mix non blocking with asynchronous I/O.

NIO.2: Asynchronous I/O (JDK version 7.0)

- Grizzly supports NIO.2. Switching an application from using NIO.1 to NIO.2 is quite simple
- Bytes are delivered the same way, independently of NIO.1 or NIO.2:

```
// Instead of TCPSelectorHandler
controller.addIOHandler(new TCPAIOHandler());

//Instead of using ReadFilter
AIOReadFilter readFilter = new AIOReadFilter();
protocolChain.addFilter(readFilter);
```

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Summary

- Project Grizzly is a simple NIO framework.
  - With less than 50 lines, you can create power client or server side components.
  - Support NIO.1 and NIO.2.
  - You have control of the framework: everything can be customized!
- HTTP module makes it easy to build WebServer extension
  - Jersey, blog-city.com, Netbeans™ software, Ning, Red Hat REST Impl, RESTlet, GlassFish v1|2|3, Sailfin Load Balancer, JXTA, and many many more!
- Healthy community: get a response in less than 2 hours :-)!

For More Information

- Grizzly:
  - http://grizzly.dev.java.net
- Jeanfrancois's blog:
  - http://weblogs.java.net/blog/jfarcand/
- Alexey's blog:
  - http://blogs.sun.com/oleksiys/
- Project Grizzly mailing lists,
  - dev@grizzly.dev.java.net
  - users@dev.grizzly.java.net

THANK YOU

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Sun Microsystems

TS-4883