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Reactive Java EE - Let Me Count the Ways!

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Agenda

- What Exactly is Reactive?
- Touring Reactive in Java EE
- Bearable Reactive with Java SE 8?

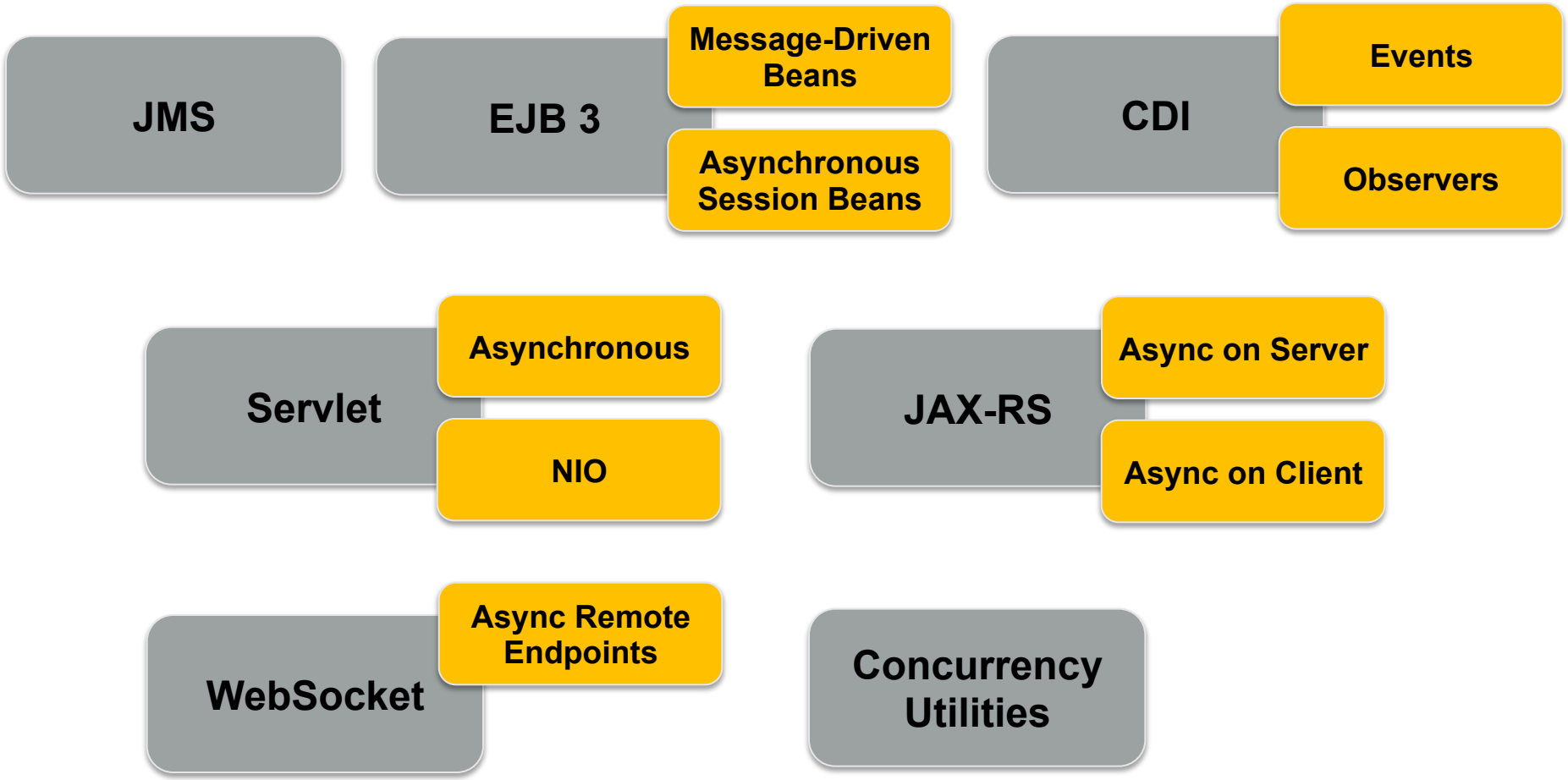
Reactive: What's in a Name?

- "Reactive" fairly old but incredibly vague term
  - A big hurdle to broad adoption by average developers
- Sound core principals perhaps co-opted by marketing concerns?
  - Event driven
  - Asynchronous
  - Non-blocking
  - Message driven
- Some overloaded concerns to very simple core principals attempted to be added on more recently
  - Responsive, resilient, elastic, adaptive, fault-tolerant, scalable, etc
  - These really don't have that much to do with Reactive concepts proper
  - Long met by Java EE runtimes

What's the Big Deal?

- Reactive has always been an important software engineering technique!
  - More responsive user experience
  - High throughput, optimal hardware/CPU utilization
  - Loose coupling, complex event processing
- Will potentially become even more important
  - Internet of Things (IoT), device-to-device communication
  - Mobile, large global concurrent user bases, more chatty applications
- Not necessarily a panacea
  - Asynchronous, event driven code is always harder to write, maintain than synchronous, blocking code
  - Horizontal/hardware scalability can be a cheaper/more maintainable answer

Reactive Java EE



JMS and Message Driven Beans

- JMS one of the oldest APIs in Java EE, strongly aligned with Reactive principles
  - Message oriented middleware
  - Message/event driven, asynchronous, loosely coupled, reliable, transactional, durable, fault tolerant, error tolerant, clustered
- Message Driven Beans primary vehicle for JMS message handling in Java EE
  - Just POJOs with annotations (metadata)
  - Transactional, thread-safe, pooled, reliable, load-balanced, fault-tolerant, error-tolerant

JMS Send

```
@Inject JMSContext jmsContext;
@Resource(lookup = "jms/HandlingEventRegistrationAttemptQueue")
Destination handlingEventQueue;
...
public void receivedHandlingEventRegistrationAttempt(
    HandlingEventRegistrationAttempt attempt) {
  ...
  jmsContext.createProducer()
      .setDeliveryMode(DeliveryMode.PERSISTENT) // The default :-)
      .setPriority(LOW_PRIORITY)
      .setDisableMessageID(true)
      .setDisableMessageTimestamp(true)
      .setStringProperty("source", source)
      .send(handlingEventQueue, attempt);
}
```

JMS MDB

```
@MessageDriven(activationConfig = {
  @ActivationConfigProperty(propertyName = "destinationType",
    propertyValue = "javax.jms.Queue"),
  @ActivationConfigProperty(propertyName = "destinationLookup",
    propertyValue = "jms/HandlingEventRegistrationAttemptQueue"),
  @ActivationConfigProperty(propertyName = "messageSelector",
    propertyValue = "source = 'mobile'")})
public class HandlingEventRegistrationAttemptConsumer
    implements MessageListener {
  ...
  public void onMessage(Message message) {
     ...
     HandlingEventRegistrationAttempt attempt
         = message.getBody(HandlingEventRegistrationAttempt.class);
     ...
  }
}
```

Even Better with JMS 2.1?

```
@ApplicationScoped
@MaxConcurrency(10)
public class HandlingEventRegistrationAttemptConsumer {
  @JmsListener(
     destinationLookup="jms/HandlingEventRegistrationAttemptQueue",
     selector="source = 'mobile'",
     batchSize=10, retry=5, retryDelay=7000,
     orderBy=TIMESTAMP)
  public void onEventRegistrationAttempt(
      HandlingEventRegistrationAttempt... attempts) {
    ...
  }
}
```

Asynchronous Session Beans

- Dead simple asynchrony at the component level
  - Just an annotation on a POJO
  - Simple return type: void (fire-and-forget) or Future<V> (client processes asynchronous results)
- Great when all that is required is greater throughput or responsiveness
  - Still transactional, thread-safe, pooled
  - Not loosely coupled, persistent, fault tolerant or error tolerant (client must explicitly handle errors)

Asynchronous Session Bean

```
@Stateless
public class ReportGeneratorService {
  @Asynchronous
  public Future<Report> generateReport(ReportParameters params){
    try{
      Report report = renderReport(params);
      return new AsyncResult(report);
    } catch(ReportGenerationException e) {
      return new AsyncResult(new ErrorReport(e));
    }
```

```
@Asynchronous
public void processPayment(Payment payment){
  // CPU/IO heavy tasks to process a payment
}
```

Asynchronous Session Bean Client

```
@Inject ReportGeneratorService reportGeneratorService;
...
Future<Report> future =
    reportGeneratorService.generateReport(parameters);
...
if (future.isDone()) {
    Report report = future.get();
    ...
}
...
future.cancel(true);
```

@Asynchronous + CompletableFuture?

```
@Asynchronous
public CompletableFuture<Confirmation> processPayment(
    Order order) {
  ...
  Confirmation status = ...;
  return
    CompletableFuture<Confirmation>.completedFuture(status);
}
```

```
paymentService
    .processPayment(order)
    .thenAccept(
        confirmation -> System.out.println(confirmation));
```

CDI Events/Observers

- Compact, simple, elegant, type-safe events
  - Essentially the observer pattern formalized via a DI framework and annotations
- Offers excellent solution to loose-coupling and type-safe filtering/ chaining, but not much else including asynchrony (not yet anyway)
  - Can be one-to-one or one-to-many

CDI Events

```
@Inject @CargoInspected Event<Cargo> cargoInspected;
...
public void inspectCargo(TrackingId trackingId) {
   ...
   cargoInspected.fire(cargo);
}
```

```
public void onCargoInspected(
     @Observes @CargoInspected Cargo cargo) {
```

```
@Qualifier
@Retention(RUNTIME) @Target({FIELD, PARAMETER})
public @interface CargoInspected {}
```

Asynchronous CDI Events?

```
@Inject @CargoInspected Event<Cargo> cargoInspected;
...
public void inspectCargo(TrackingId trackingId) {
   ...
   cargoInspected.fireAsync(cargo);
}
```

```
public void onCargoInspected(
     @Observes(async=true) @CargoInspected Cargo cargo) {
```

Asynchronous Servlets and NIO

- Asynchronous Servlets maximize throughput/thread utilization
  - Decouple connection from request thread
  - Return request thread back to pool
  - Handle IO/CPU heavy work on separate backend thread
  - Close cached connection when done
- NIO removes possible thread blocks during slow read/write
  - Get notified when the IO channel might be ready
  - Only read/write when IO channel is ready
  - Obvious need when Servlet IO is particularly heavy, otherwise a very complex solution

Asynchronous Servlet

```
@WebServlet(urlPatterns={"/report"}, asyncSupported=true)
public class AsyncServlet extends HttpServlet {
  public void doGet(HttpServletRequest request,
      HttpServletResponse response) {
    ...
    final AsyncContext asyncContext = request.startAsync();
    asyncContext.start(() -> {
      ReportParameters parameters =
          parseReportParameters(asyncContext.getRequest());
      Report report =  generateReport(parameters);
      printReport(report, asyncContext.getResponse());
      asyncContext.complete();
    });
  }
}
```

Asynchronous Servlet NIO (Output Stream)

```
private void printReport(Report report,
    AsyncContext context) {
  ServletOutputStream output =
      context.getResponse().getOutputStream();
  WriteListener writeListener = new ReportWriteListener(
      output, report, context);
  output.setWriteListener(writeListener);
}
```

Asynchronous Servlet NIO (Write Listener)

```
class ReportWriteListener implements WriteListener {
  private ServletOutputStream output = null;
  private InputStream input = null;
  private AsyncContext context = null;

  ReportWriteListener(ServletOutputStream output, Report report,
      AsyncContext context) {
    this.output = output;
    this.input = report.asPdfStream();
    this.context = context;
  }
  ...
```

Asynchronous Servlet NIO (Write Listener)

```
  ...
  public void onWritePossible() throws IOException {
    byte[] chunk = new byte[256];
    int read = 0;
    while (output.isReady() && (read = input.read(chunk)) != -1)
      output.write(chunk, 0, read);

    if (read == -1)
      context.complete();
  }

  public void onError(Throwable t) {
    context.complete();
    t.printStackTrace();
  }
}
```

Asynchronous JAX-RS

- Asynchronous capabilities newly added to JAX-RS 2/Java EE 7
  - Both on the server and client side
- Server-side essentially identical to Servlet 3 async
  - Nicer declarative syntax
- Client API async capabilities very symmetric to synchronous API
  - Both Futures and callbacks supported
- No NIO yet, but could be included in Java EE 8

Asynchronous JAX-RS Resource

```
@Stateless
@Path("/reports")
public class ReportsResource {
   ...
   @Path("{id}")
   @GET
   @Produces({"application/pdf"})
   @Asynchronous
   public void generateReport(
       @PathParam("id") Long id,
       @Suspended AsyncResponse response) {
     ResponseBuilder builder =
Response.ok(renderReport(id));
     builder.header("Content-Disposition",
         "attachment; filename=report.pdf");
      response.resume(builder.build());
   }
}
```

Asynchronous JAX-RS Client

```
WebTarget target = client.target("http://.../balance")...

Future<Double> future = target.request()
                              .async().get(Double.class));
...
Double balance = future.get();
```

```
WebTarget target = client.target("http://.../balance")...

target.request().async().get(
    new InvocationCallback<Double>() {
        public void complete(Double balance) {
          // Process balance
        }
        public void failed(InvocationException e) {
          // Process error
        }
    });
```

Asynchrony/NIO in WebSocket

- WebSocket endpoints are inherently non-blocking/event-driven!
  - There's no thread-connection association in the first place
  - True for server and client side
- Writes/sends can be made asynchronously for better throughput
  - Very symmetric API for both sync and async
  - Futures or callbacks supported
  - Good idea to use asynchronous send in most cases!

Asynchronous Remote WebSocket Endpoint

```
@ServerEndpoint(value = "/chat"...)
@Singleton
public class ChatServer {
  private Set<Session> peers = new HashSet<>();

  @OnOpen
  public void onOpen(Session peer) {
    peers.add(peer);
  }

  @OnClose
  public void onClose(Session peer) {
    peers.remove(peer);
  }

  @OnMessage
  public void onMessage(ChatMessage message) {
    for (Session peer : peers) {
      ...peer.getAsyncRemote().sendObject(message)...
    }
  }
}
```

Future vs Callback

```
Future<Void> future =
    peer.getAsyncRemote().sendObject(message);
```

```
peer.getAsyncRemote().sendObject(message,
    (SendResult result) -> {
      ...
      if (!result.isOK()) {
        ...result.getException()...
      }
      ...
    });
```

Java EE Concurrency Utilities

- Allows for lower-level threading/asynchronous capabilities in Java EE in a safe, reliable, managed fashion
  - Very specialized code, custom workloads
- Fairly small extension of Java SE Concurrency Utilities
  - ManagedExecutorService
  - ManagedThreadFactory

Managed Executor Service

```
@Path("/reports")
public class ReportsResource {
  @Resource ManagedExecutorService executor;
  ...
  @Path("{id}")
  @GET
  @Produces({"application/pdf"})
  public void generateReport(
      @PathParam("id") Long id,
      @Suspended AsyncResponse response) {
    executor.execute(() -> {
      ResponseBuilder builder = Response.ok(renderReport(id));
      builder.header("Content-Disposition",
          "attachment; filename=report.pdf");
      response.resume(builder.build());
    }
  }
}
```

Executor Service API

```
public interface ManagedExecutorService
    extends ExecutorService {
  public void execute(Runnable command);

  public <T> Future<T> submit(Callable<T> task);
  public Future<?> submit(Runnable task);
  public <T> Future<T> submit(Runnable task, T result);
  ...
}
```

Java SE 8 Completable Future

- Futures and callbacks both have serious flaws
  - Especially when it comes to significantly Reactive code
- Java SE 8 CompletableFuture significantly better for Reactive programming
  - Non-blocking, event-driven, composable and functional (via lambdas)
- Easy to integrate with Java EE 7 managed executors
  - Should Java EE (and Java SE) embrace CompletableFuture more uniformly?

Looks are Deceiving…

```
Person p = ...
Assets assets = getAssets(p);
Liabilities liabilities = getLiabilities(p);
Credit credit = calculateCreditScore(assets, liabilities);

History history = getHealthHistory(p);
Health health = calculateHeathScore(history);

Coverage coverage = underwrite(credit, health);
```

The Problem with Futures (and Callbacks)

```
Person p = ...
Future<Assets> f1 = executor.submit(() -> getAssets(p));
Future<Liabilities> f2 = executor.submit(
    () -> getLiabilities(p));
Future<Credit> f3 = executor.submit(
    () -> calculateCreditScore(f1.get(), f2.get()));

// The unrelated calls below are now blocked for no reason.
Future<History> f4 = executor.submit(
    () -> getHealthHistory(p));
Future<Health> f5 = executor.submit(
    () -> calculateHeathScore(f4.get()));


// Unrelated paths join below.
Future<Coverage> f6 = executor.submit(
    () -> underwrite(f3.get(), f5.get()));
```

Callbacks don't block, but introduce callback hell…

https://github.com/m-reza-rahman/reactive_javaee/blob/master/CallbackHell.java

CompletableFuture Basics

```
@Resource ManagedExecutorService executor;
...
public CompletableFuture<Confirmation> processPayment(Order order) {
  CompletableFuture<Confirmation> future = new CompletableFuture<>();
  executor.execute(() -> {
    Confirmation status = ...
    future.complete(status);
  });
  return future;
}
```

```
paymentService
    .processPayment(order)
    .thenAccept(
        confirmation -> System.out.println(confirmation));
```

Functional Reactive to the Rescue?

```
CompletableFuture<Assets> getAssets =
    CompletableFuture.supplyAsync(
        () -> getAssets(person), executor);
CompletableFuture<Liabilities> getLiabilities =
    CompletableFuture.supplyAsync(
        () -> getLiabilities(person), executor);
CompletableFuture<Credit> calculateCreditScore =
    getAssets.thenCombineAsync(getLiabilities,
        (assets, liabilities) ->
            calculateCreditScore(assets, liabilities), executor);

CompletableFuture<Health> calculateHeathScore =
    CompletableFuture.supplyAsync(
        () -> getHealthHistory(person), executor)
            .thenApplyAsync(
                history -> calculateHeathScore(history), executor);

Coverage coverage =
    calculateCreditScore.thenCombineAsync(calculateHeathScore,
        (credit, health) -> underwrite(credit, health), executor)
            .join();
```

More Possibilities…

- Reactive JPA?
  - Last major reactive frontier for Java EE?
  - Async/NIO support in underlying database driver/JDBC
  - A specialized thread pool might help in the meanwhile?

```
CompletableFuture<List<Country>> countries =
    em.createQuery("SELECT c FROM Country c",
Country.class)
        .async().getResultList();
```

- Reactive MVC?
  - Similar to basic model in JAX-RS/Servlet
  - EJB async another possible model
  - Reactive JSF conceptually tough

Summary

- Reactive programming well established technique, may be more important in the near future
- Java EE has long had rich support for the Reactive model
- Things could be improved even more with Java EE 8
- Java SE 8 helps quite a bit to make the programming model easier
- Beyond Java EE application servers provide clustering, load-balancing, replication, failover, bandwidth throttling, resource pooling, thread pooling, caching
- Be careful – Reactive is not an easy approach to take

Resources

- Java EE Tutorials
  - http://docs.oracle.com/javaee/7/tutorial/doc/home.htm
- Java SE Tutorials
  - http://docs.oracle.com/javase/tutorial/
- Digging Deeper
  - http://docs.oracle.com/javaee/7/firstcup/doc/home.htm
  - https://glassfish.java.net/hol/
  - http://cargotracker.java.net
- Java EE Transparent Expert Groups
  - http://javaee-spec.java.net
- Java EE Reference Implementation
  - http://glassfish.org
- The Aquarium
  - http://blogs.oracle.com/theaquarium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