Consuming web services asynchronously with Futures and Rx Observables

Chris Richardson

Author of POJOs in Action

Founder of the original CloudFoundry.com

@crichardson

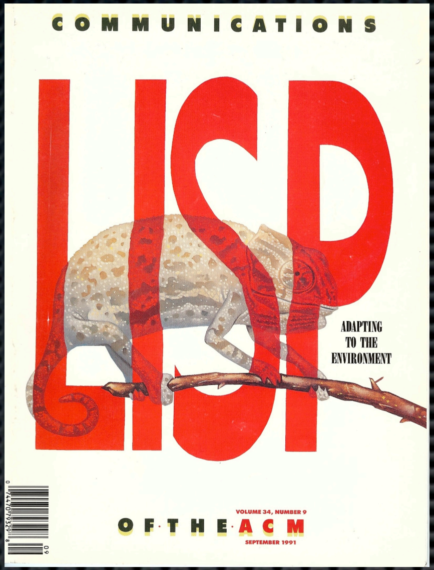
chris@chrisrichardson.net

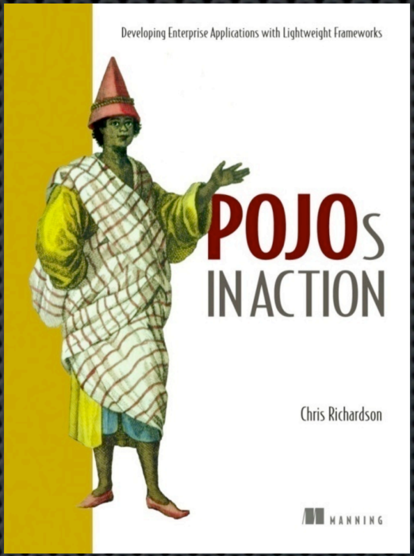
http://plainoldobjects.com

Presentation goal

Learn how to use (Scala) Futures and Rx Observables to write simple yet robust and scalable concurrent code

About Chris

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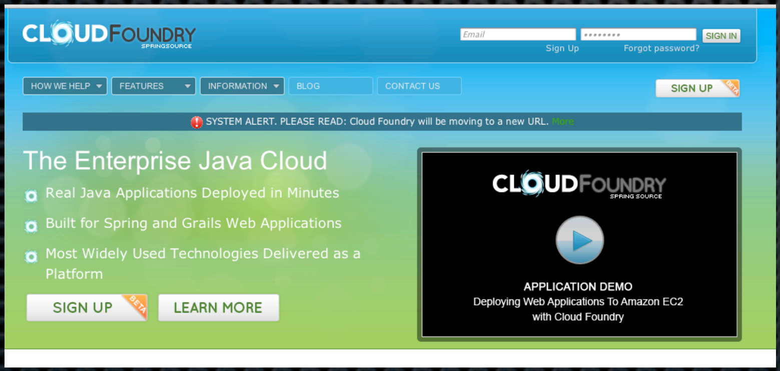
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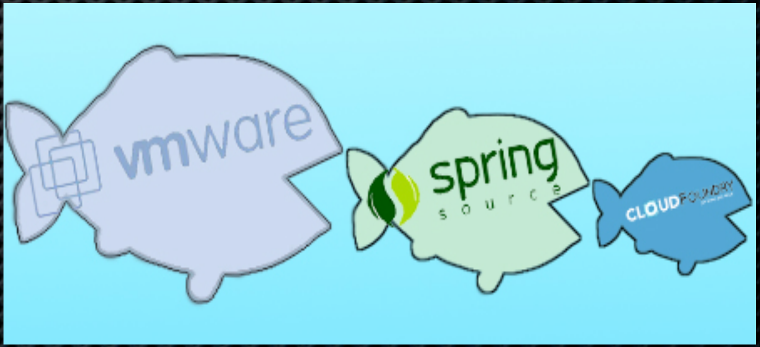

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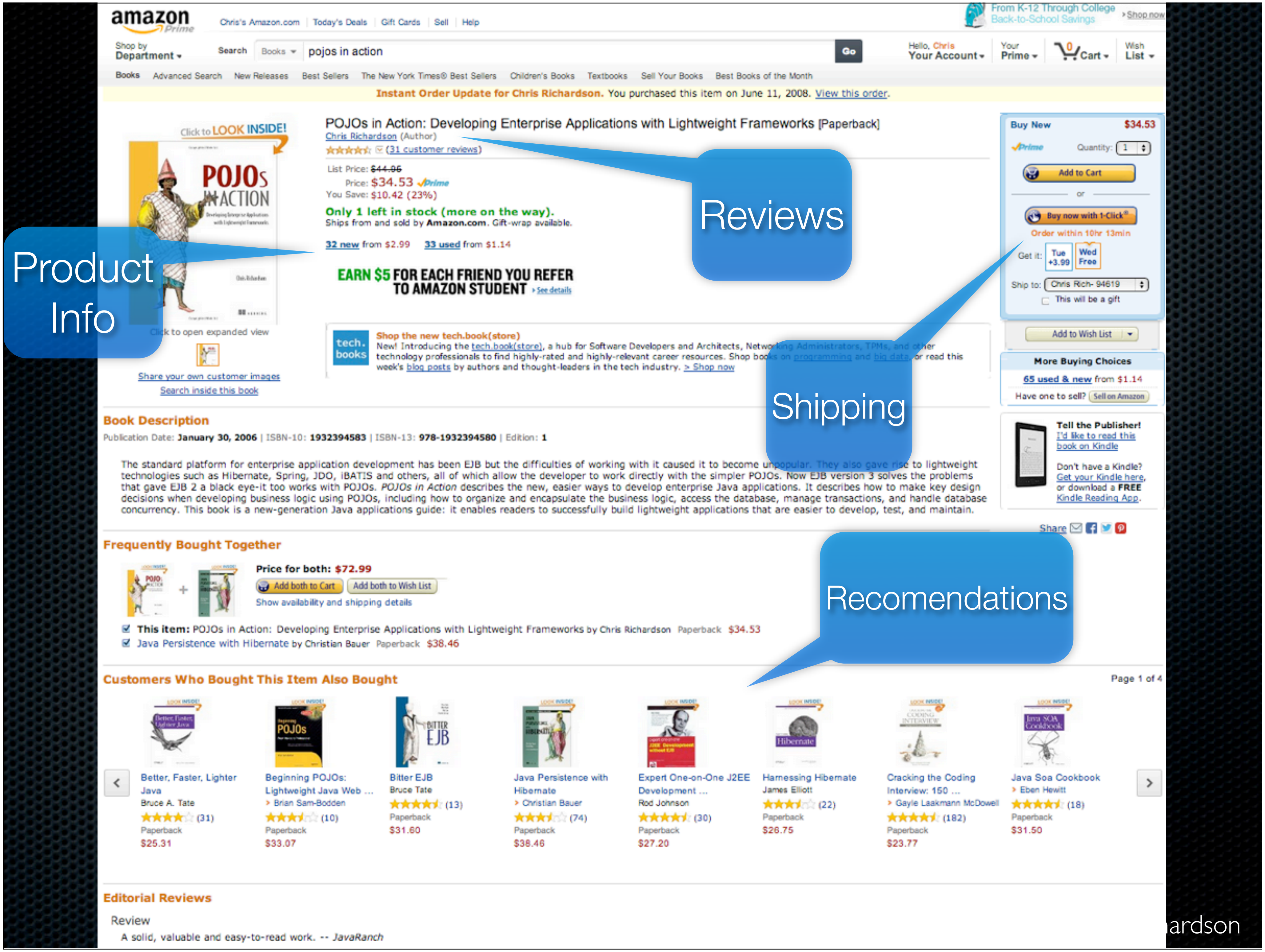
About Chris

- Founder of a buzzword compliant (stealthy, social, mobile, big data, machine learning, ...) startup
- Consultant helping organizations improve how they architect and deploy applications using cloud, micro services, polyglot applications, NoSQL, ...

Agenda

- The need for concurrency
- Simplifying concurrent code with Futures
- Consuming asynchronous streams with Reactive Extensions

Let’s imagine you are building an online store



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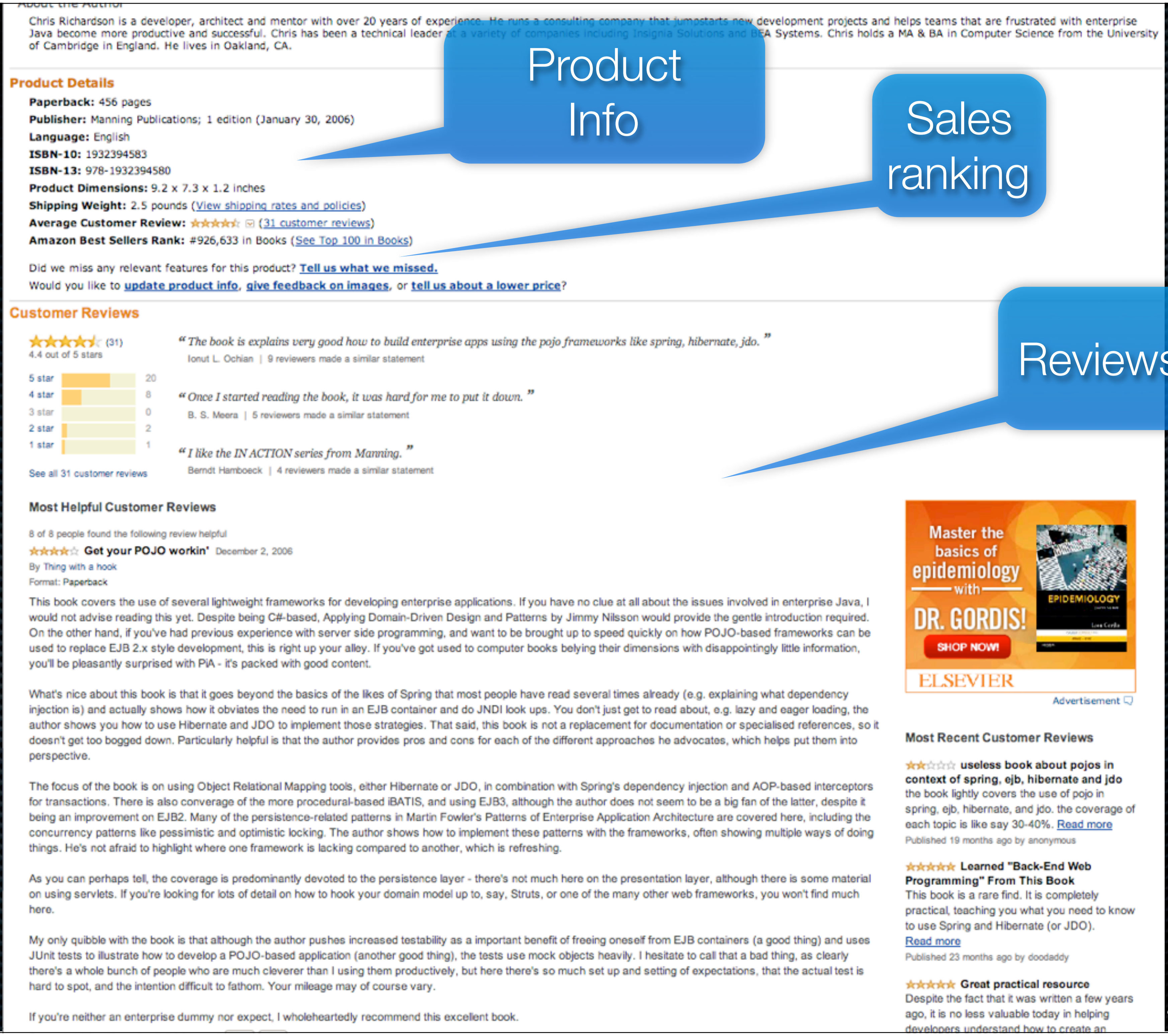

Chris Richardson is a developer, architect and mentor with over 20 years of experience. He runs a consulting company that jumpstarts new development projects and helps teams that are frustrated with enterprise Java become more productive and successful. Chris has been a technical leader at a variety of companies including Insignia Solutions and BEA Systems. Chris holds a MA & BA in Computer Science from the University of Cambridge in England. He lives in Oakland, CA.

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8 of 8 people found the following review helpful
★★★★☆ **Get your POJO workin'** December 2, 2006
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This book covers the use of several lightweight frameworks for developing enterprise applications. If you have no clue at all about the issues involved in enterprise Java, I would not advise reading this yet. Despite being C#-based, Applying Domain-Driven Design and Patterns by Jimmy Nilsson would provide the gentle introduction required. On the other hand, if you've had previous experience with server side programming, and want to be brought up to speed quickly on how POJO-based frameworks can be used to replace EJB 2.x style development, this is right up your alley. If you've got used to computer books belying their dimensions with disappointingly little information, you'll be pleasantly surprised with PiA - it's packed with good content.

What's nice about this book is that it goes beyond the basics of the likes of Spring that most people have read several times already (e.g. explaining what dependency injection is) and actually shows how it obviates the need to run in an EJB container and do JNDI look ups. You don't just get to read about, e.g. lazy and eager loading, the author shows you how to use Hibernate and JDO to implement those strategies. That said, this book is not a replacement for documentation or specialised references, so it doesn't get too bogged down. Particularly helpful is that the author provides pros and cons for each of the different approaches he advocates, which helps put them into perspective.

The focus of the book is on using Object Relational Mapping tools, either Hibernate or JDO, in combination with Spring's dependency injection and AOP-based interceptors for transactions. There is also converage of the more procedural-based iBATIS, and using EJB3, although the author does not seem to be a big fan of the latter, despite it being an improvement on EJB2. Many of the persistence-related patterns in Martin Fowler's Patterns of Enterprise Application Architecture are covered here, including the concurrency patterns like pessimistic and optimistic locking. The author shows how to implement these patterns with the frameworks, often showing multiple ways of doing things. He's not afraid to highlight where one framework is lacking compared to another, which is refreshing.

As you can perhaps tell, the coverage is predominantly devoted to the persistence layer - there's not much here on the presentation layer, although there is some material on using servlets. If you're looking for lots of detail on how to hook your domain model up to, say, Struts, or one of the many other web frameworks, you won't find much here.

My only quibble with the book is that although the author pushes increased testability as a important benefit of freeing oneself from EJB containers (a good thing) and uses JUnit tests to illustrate how to develop a POJO-based application (another good thing), the tests use mock objects heavily. I hesitate to call that a bad thing, as clearly there's a whole bunch of people who are much cleverer than I using them productively, but here there's so much set up and setting of expectations, that the actual test is hard to spot, and the intention difficult to fathom. Your mileage may of course vary.

If you're neither an enterprise dummy nor expect, I wholeheartedly recommend this excellent book.

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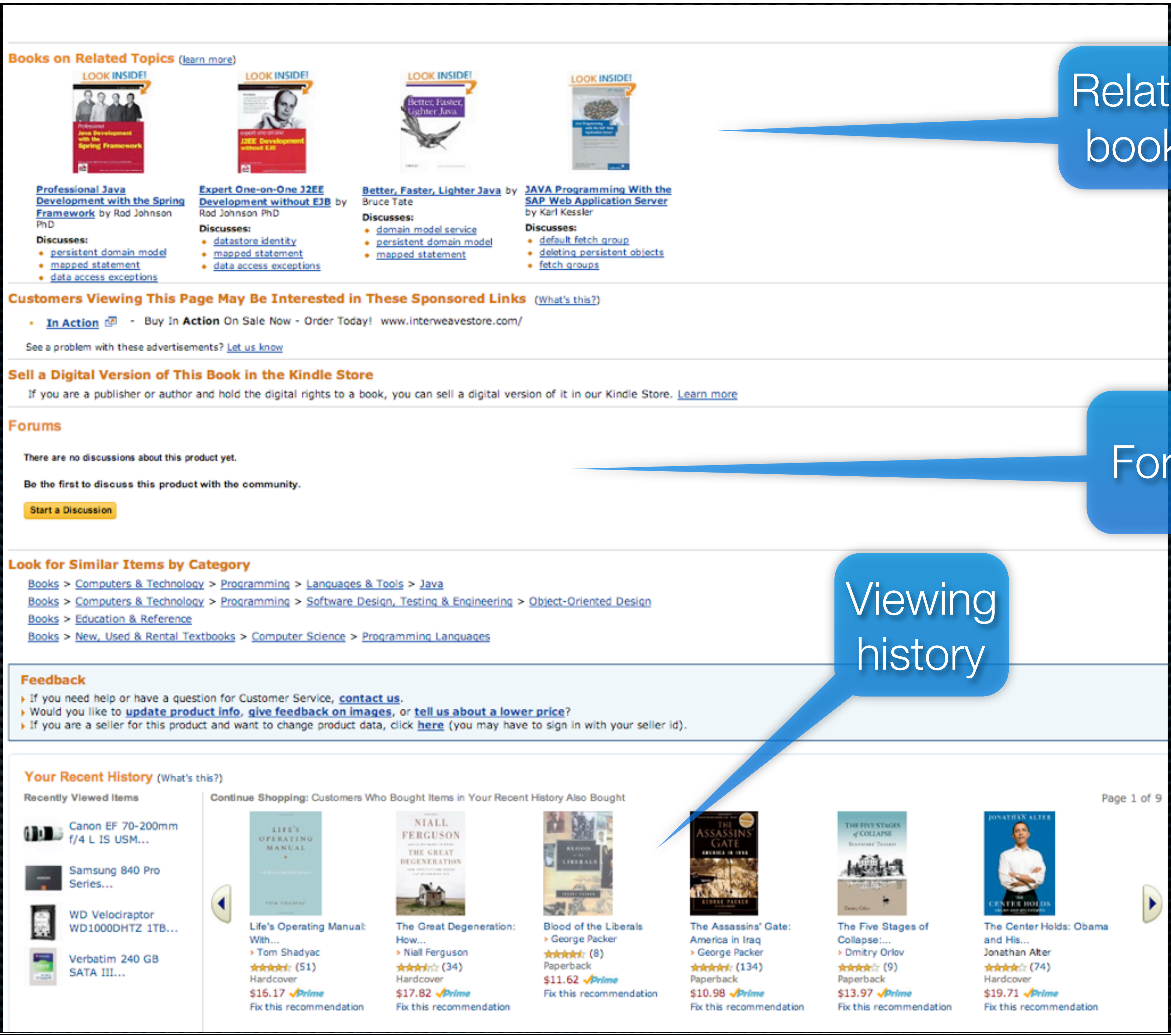

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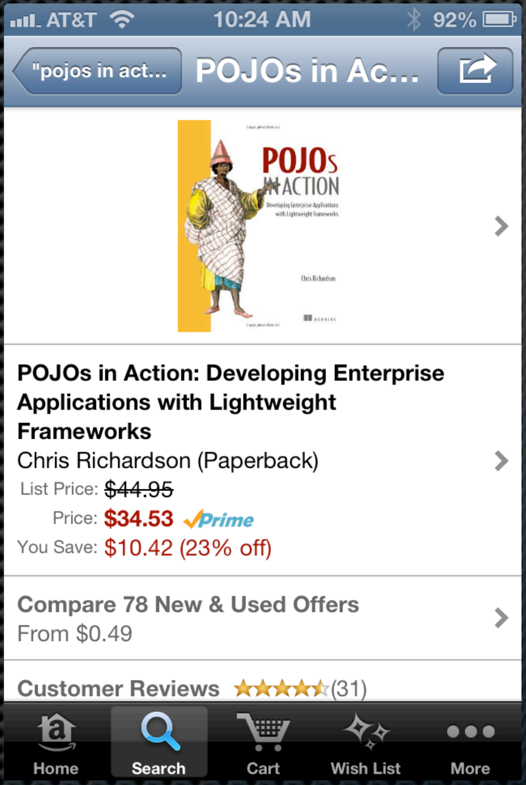

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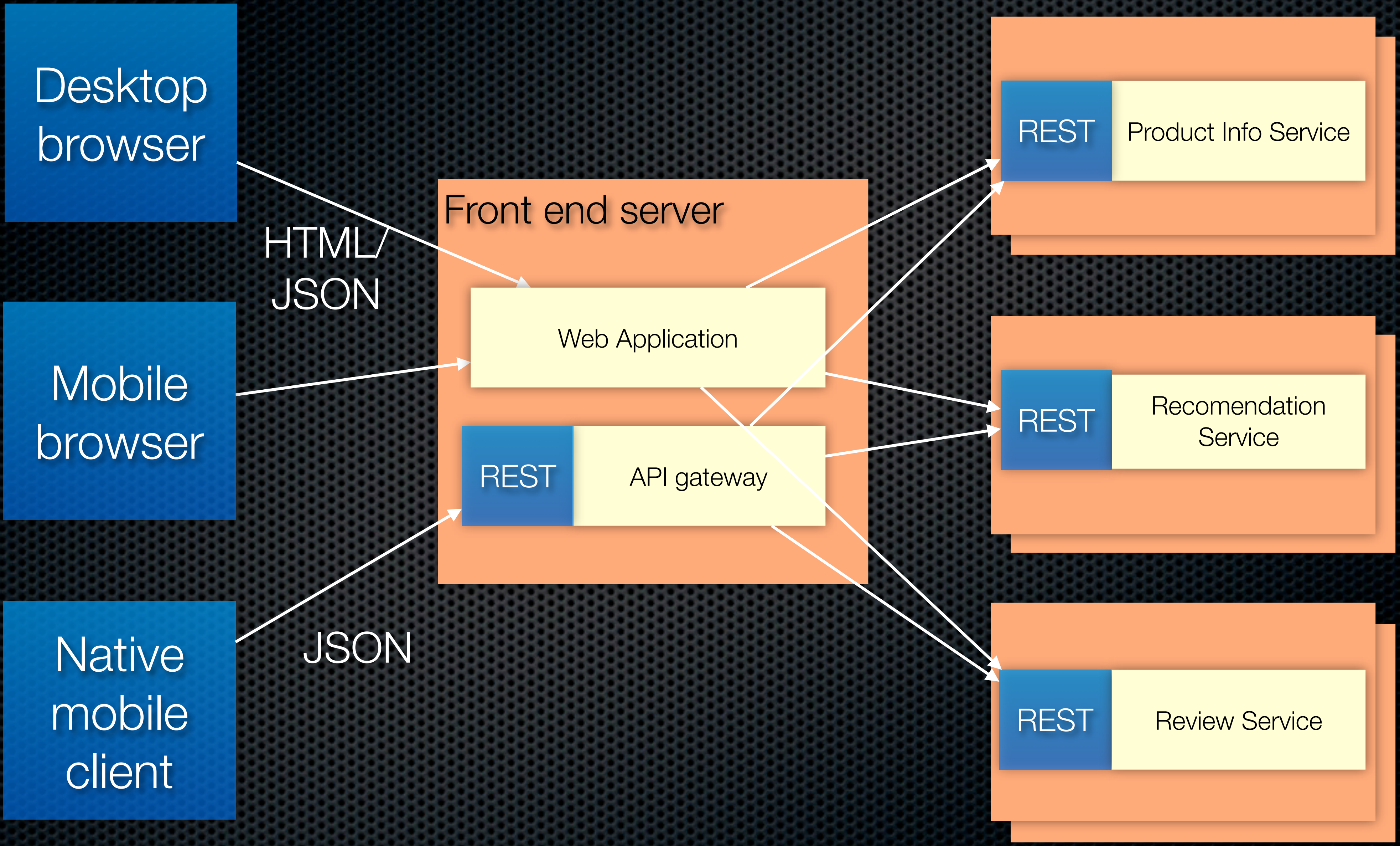
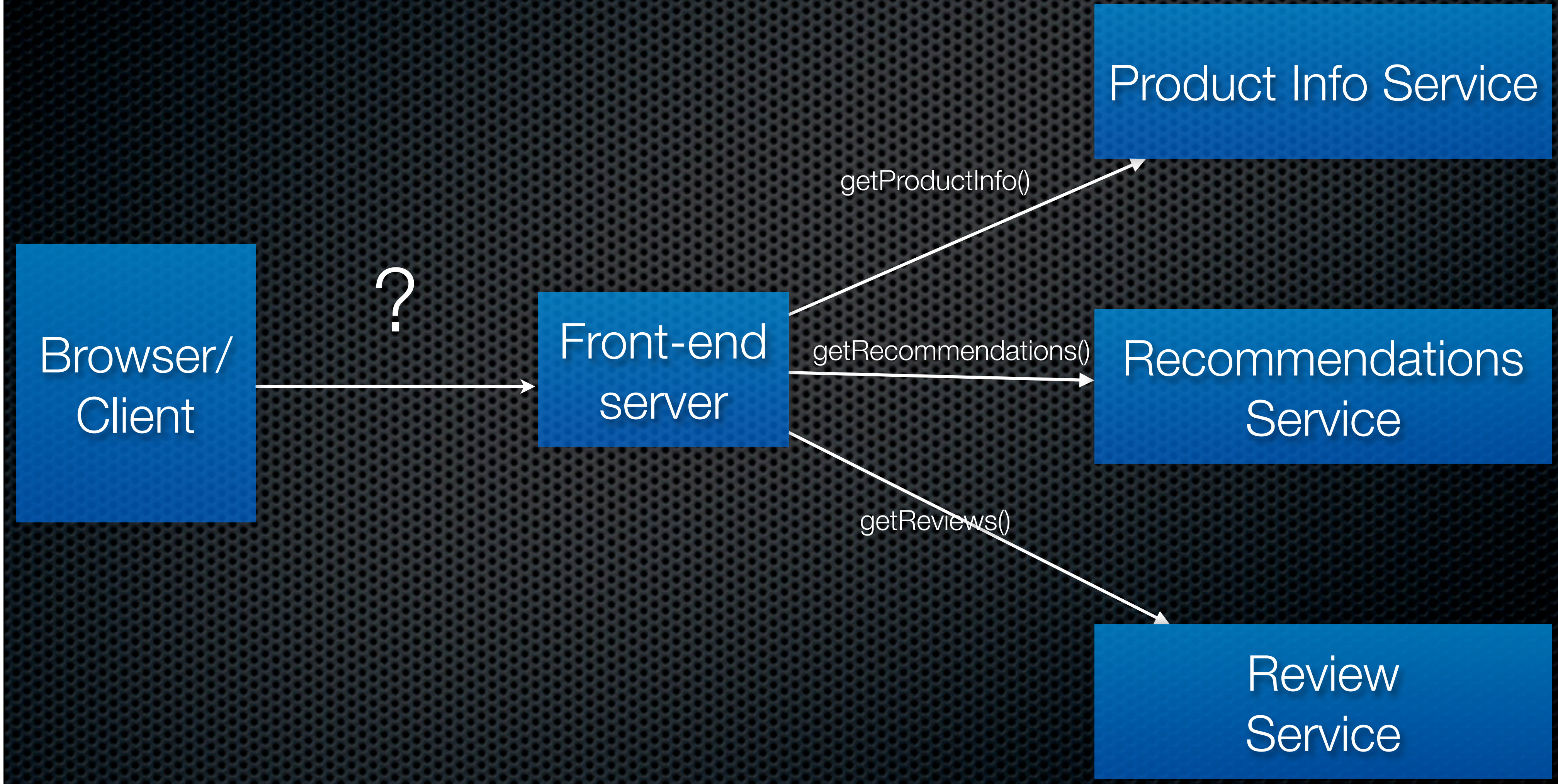
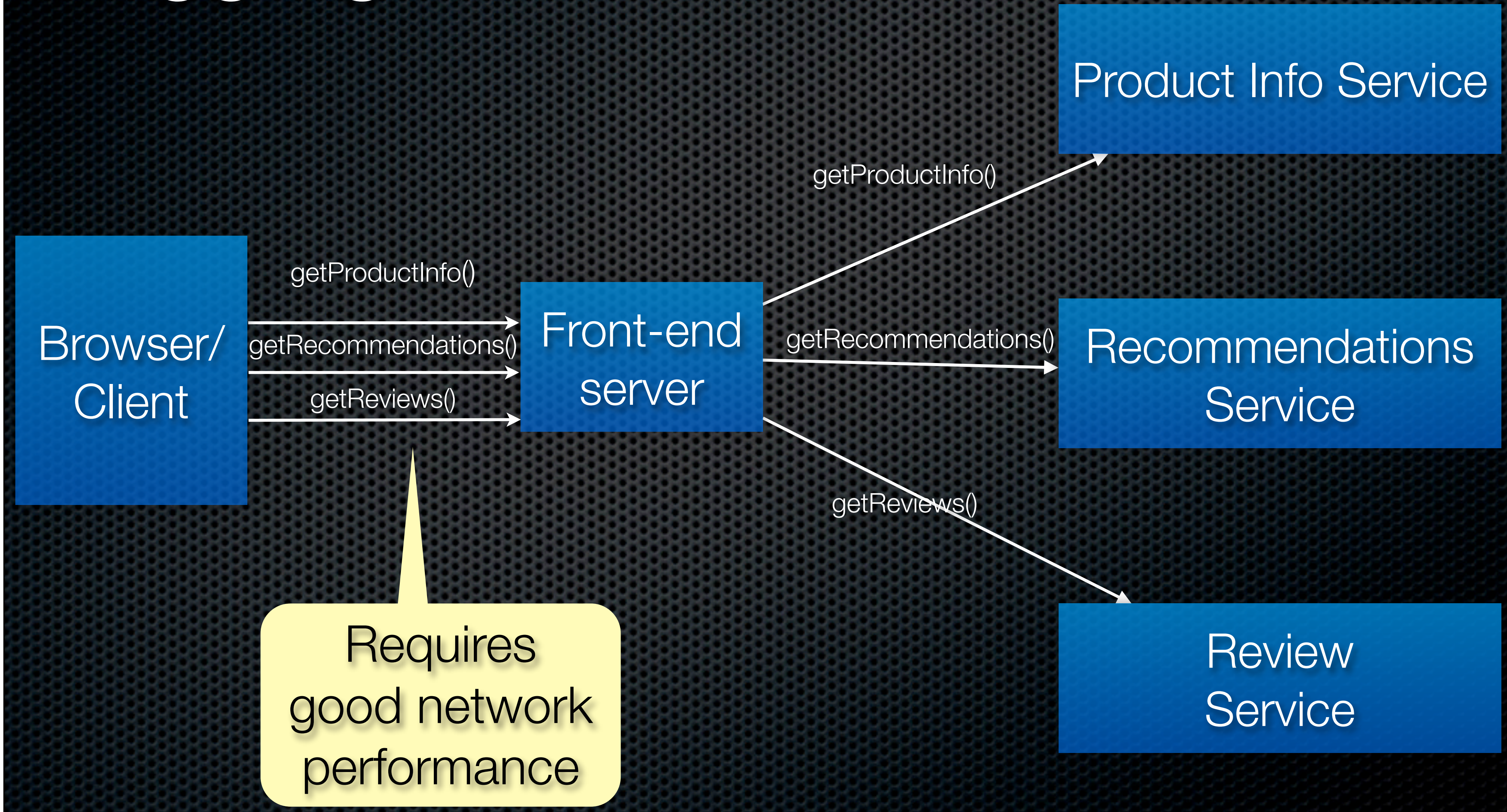
Application architecture



How does the client get product details?



Product details - client-side aggregation



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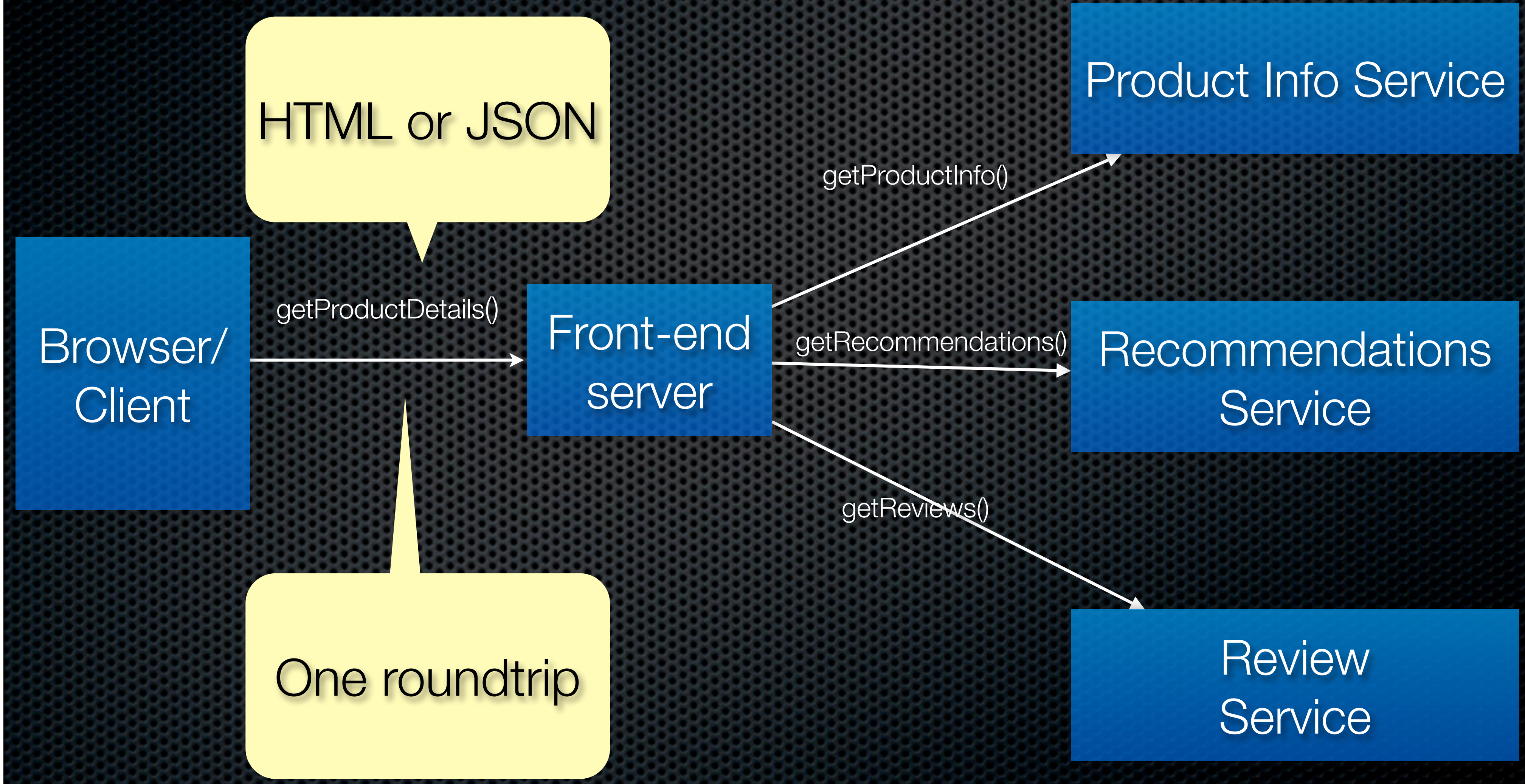
Product details - server-side aggregation



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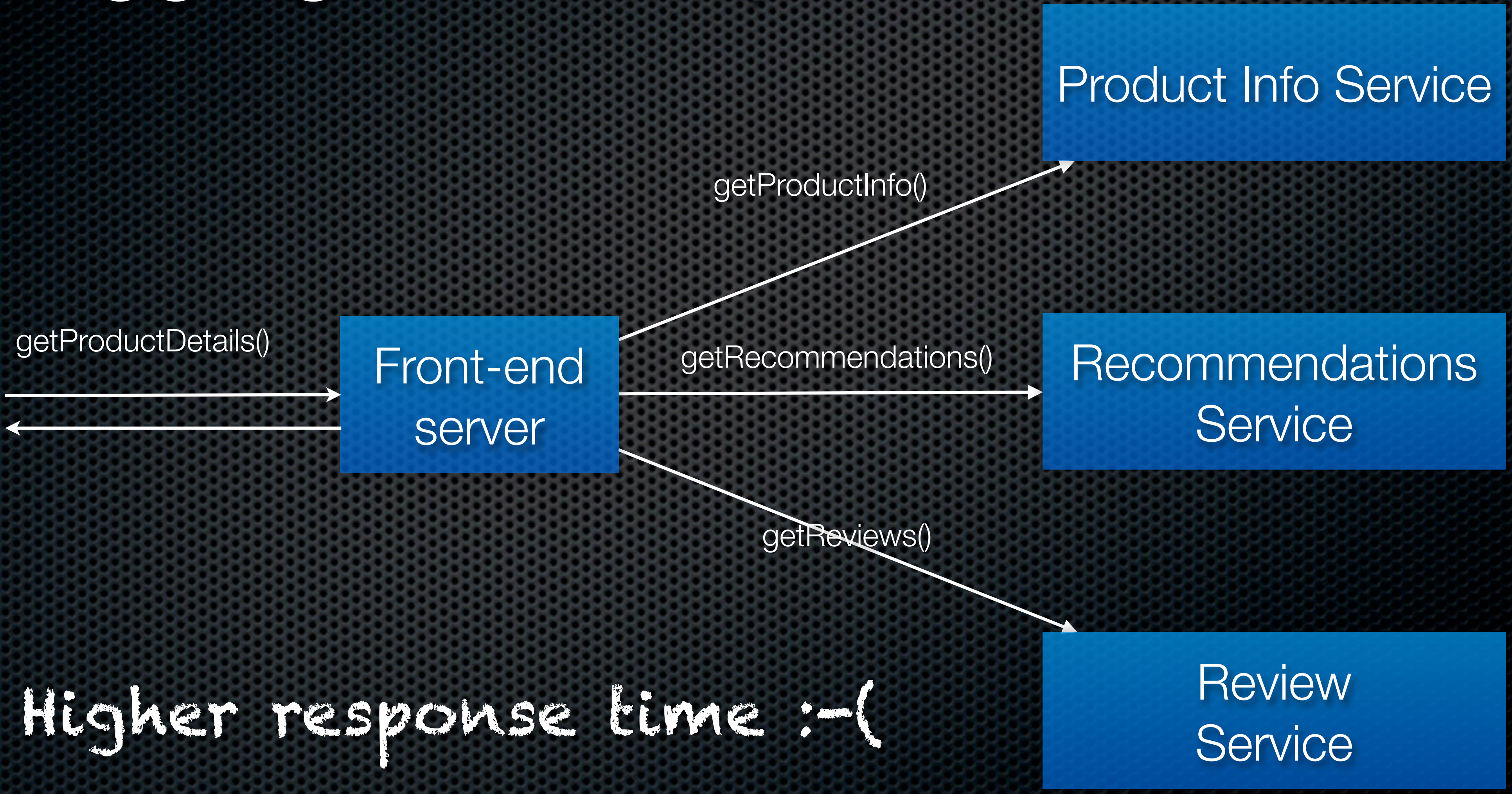
Product details - server-side aggregation: sequentially



Higher response time :-(

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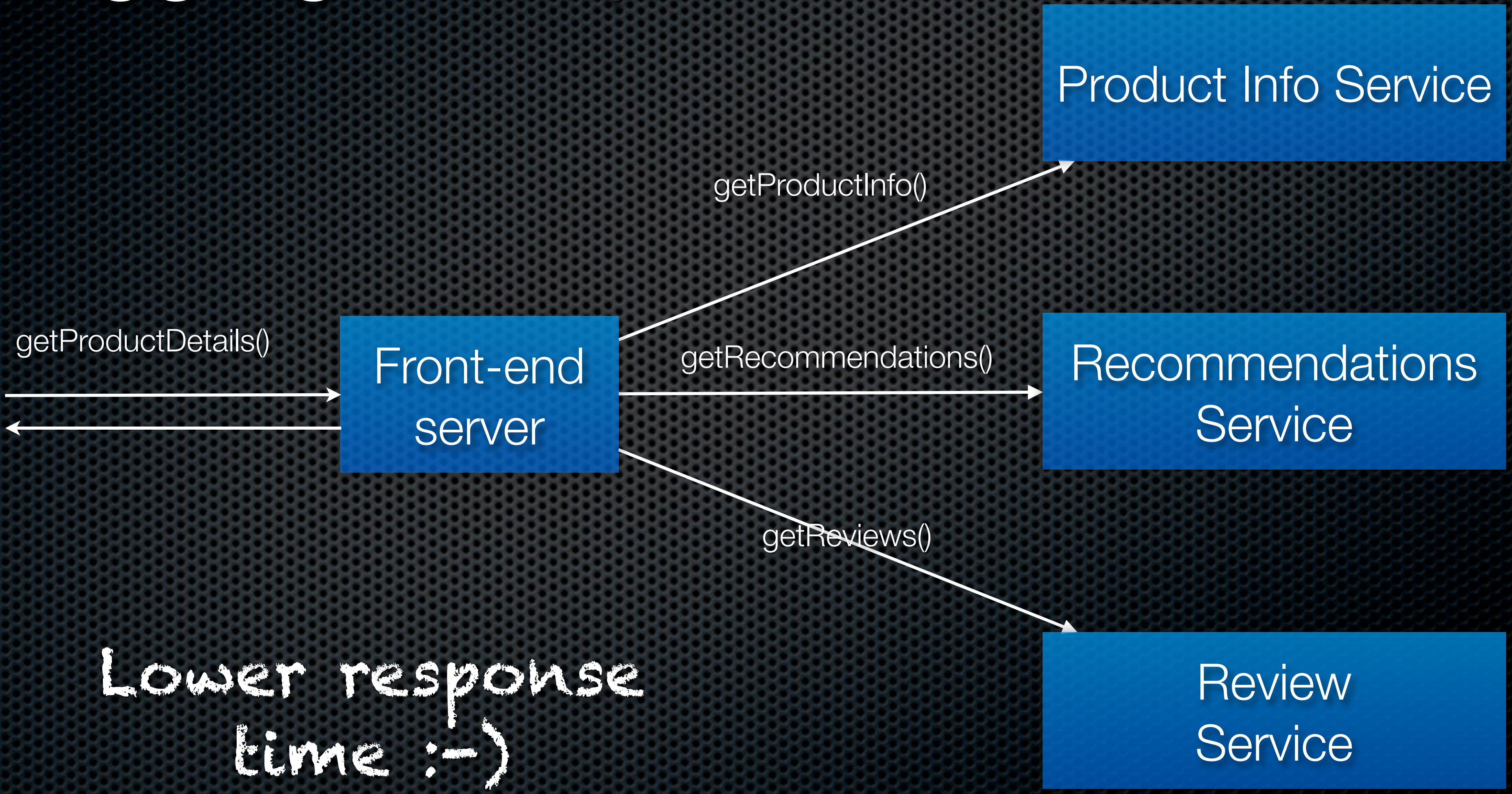
Product details - server-side aggregation: parallel



Lower response time :-)

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Implementing a concurrent REST client

- Thread-pool based approach
  - executorService.submit(new Callable(...))
  - Simpler but less scalable - lots of idle threads consuming memory
- Event-driven approach
  - NIO with completion callbacks
  - More complex but more scalable

And it must handle partial failures

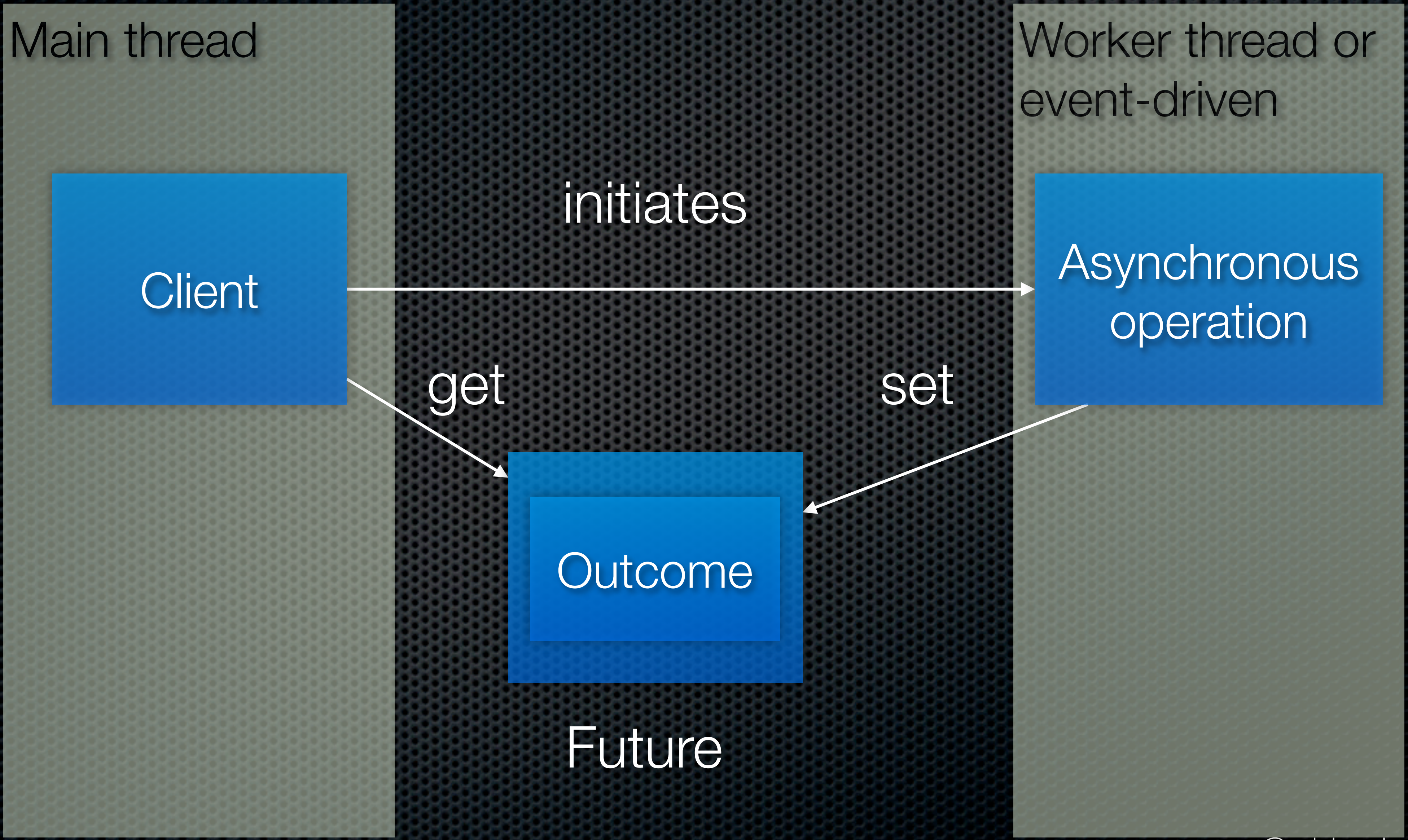
Agenda

- The need for concurrency
- Simplifying concurrent code with Futures
- Consuming asynchronous streams with Reactive Extensions

Futures are a great concurrency abstraction

http://en.wikipedia.org/wiki/Futures_and_promises

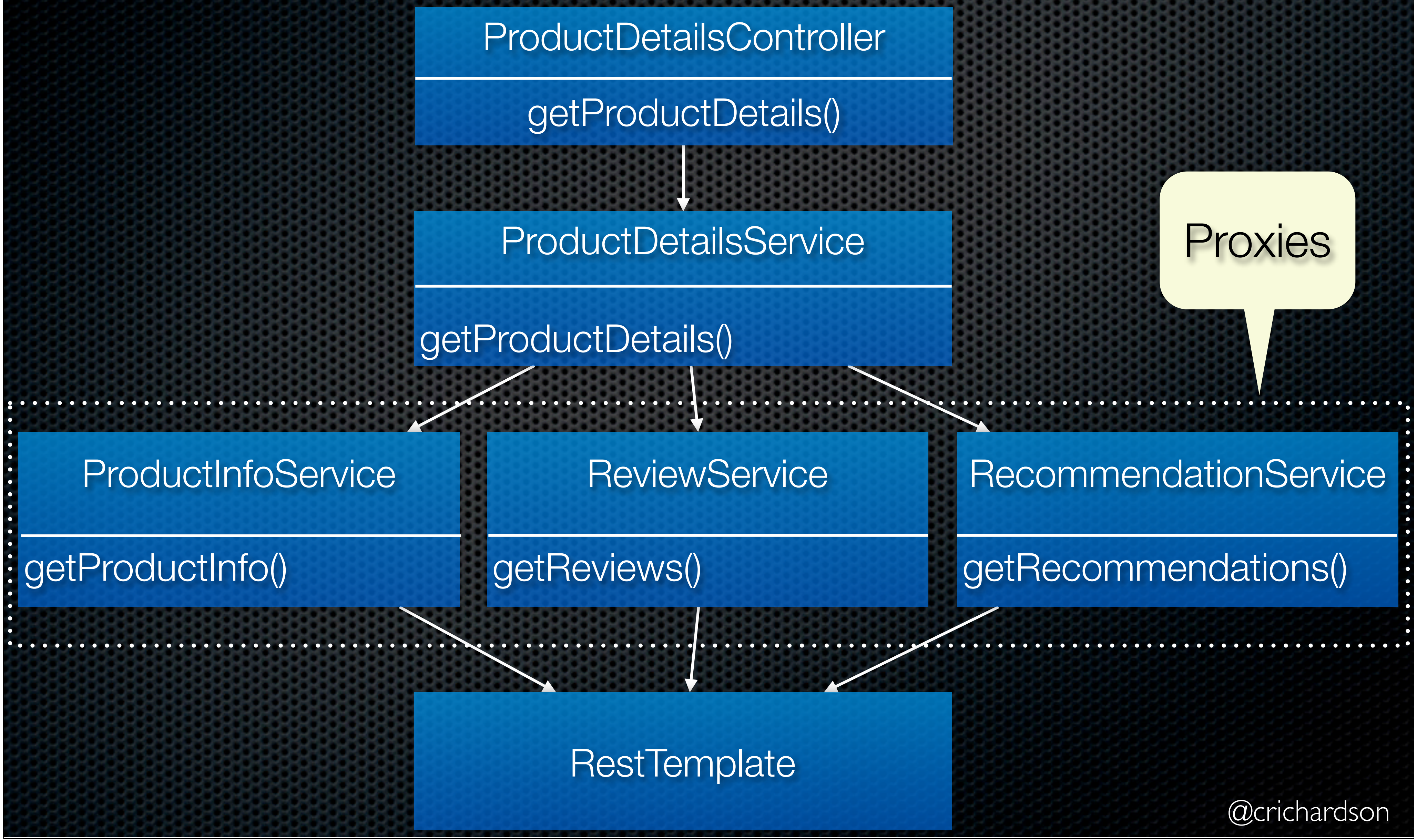
How futures work



Benefits

- Simple way for two concurrent activities to communicate safely
- Abstraction:
  - Client does not know how the asynchronous operation is implemented
- Easy to implement scatter/gather:
  - Scatter: Client can invoke multiple asynchronous operations and gets a Future for each one.
  - Gather: Get values from the futures

Front-end server design: handling GetProductDetails request



REST client using Spring @Async

```
trait ProductInfoService {
  def getProductInfo(productId: Long):
               java.util.concurrent.Future[ProductInfo]
}
```

```
@Component
class ProductInfoServiceImpl extends ProducInfoService {

  val restTemplate : RestTemplate = ...

  @Async
  def getProductInfo(productId: Long) = {
    new AsyncResult(restTemplate.getForObject(....)...)
  }

}
```

Execute asynchronously in thread pool

A fulfilled Future

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ProductDetailsService

```
@Component
class ProductDetailsService
       @Autowired()(productInfoService: ProductInfoService,
                            reviewService: ReviewService,
                            recommendationService: RecommendationService) {

  def getProductDetails(productId: Long): ProductDetails = {
    val productInfoFuture = productInfoService.getProductInfo(productId)
    val recommendationsFuture =
              recommendationService.getRecommendations(productId)
    val reviewsFuture = reviewService.getReviews(productId)
    val productInfo = productInfoFuture.get(300, TimeUnit.MILLISECONDS)
    val recommendations =
         recommendationsFuture.get(10, TimeUnit.MILLISECONDS)
    val reviews = reviewsFuture.get(10, TimeUnit.MILLISECONDS)

    ProductDetails(productInfo, recommendations, reviews)
  }

}
```

ProductController

```
@Controller
class ProductController
    @Autowired()(productDetailsService : ProductDetailsService)
{

  @RequestMapping(Array("/productdetails/{productId}"))
  @ResponseBody
  def productDetails(@PathVariable productId: Long) =
     productDetailsService.getProductDetails(productId)
```

Not bad but...

```
class ProductDetailsService
  def getProductDetails(productId: Long): ProductDetails = {

    val productInfo =
       productInfoFuture.get(300, TimeUnit.MILLISECONDS)
```

Gathering blocks Tomcat thread until all Futures complete

Not so scalable :-(

... and also...

- Java Futures work well for a single-level of asynchronous execution

BUT

- #fail for more complex, scalable scenarios
- Difficult to compose and coordinate multiple concurrent operations
- See this blog post for more details:

http://techblog.netflix.com/2013/02/rxjava-netflix-api.html

Better: Futures with callbacks ⇒ no blocking!

```
def asyncSquare(x : Int)
       : Future[Int] = ... x * x...

val f = asyncSquare(25)

f onSuccess {
  case x : Int => println(x)
}
f onFailure {
  case e : Exception => println("exception thrown")
}
```

Partial function applied to successful outcome

Applied to failed outcome

Guava ListenableFutures, Spring 4 ListenableFuture
Java 8 CompletableFuture, **Scala Futures**

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But
callback-based scatter/gather
⇒
Messy, tangled code
(aka. callback hell)

Composable futures hide the mess

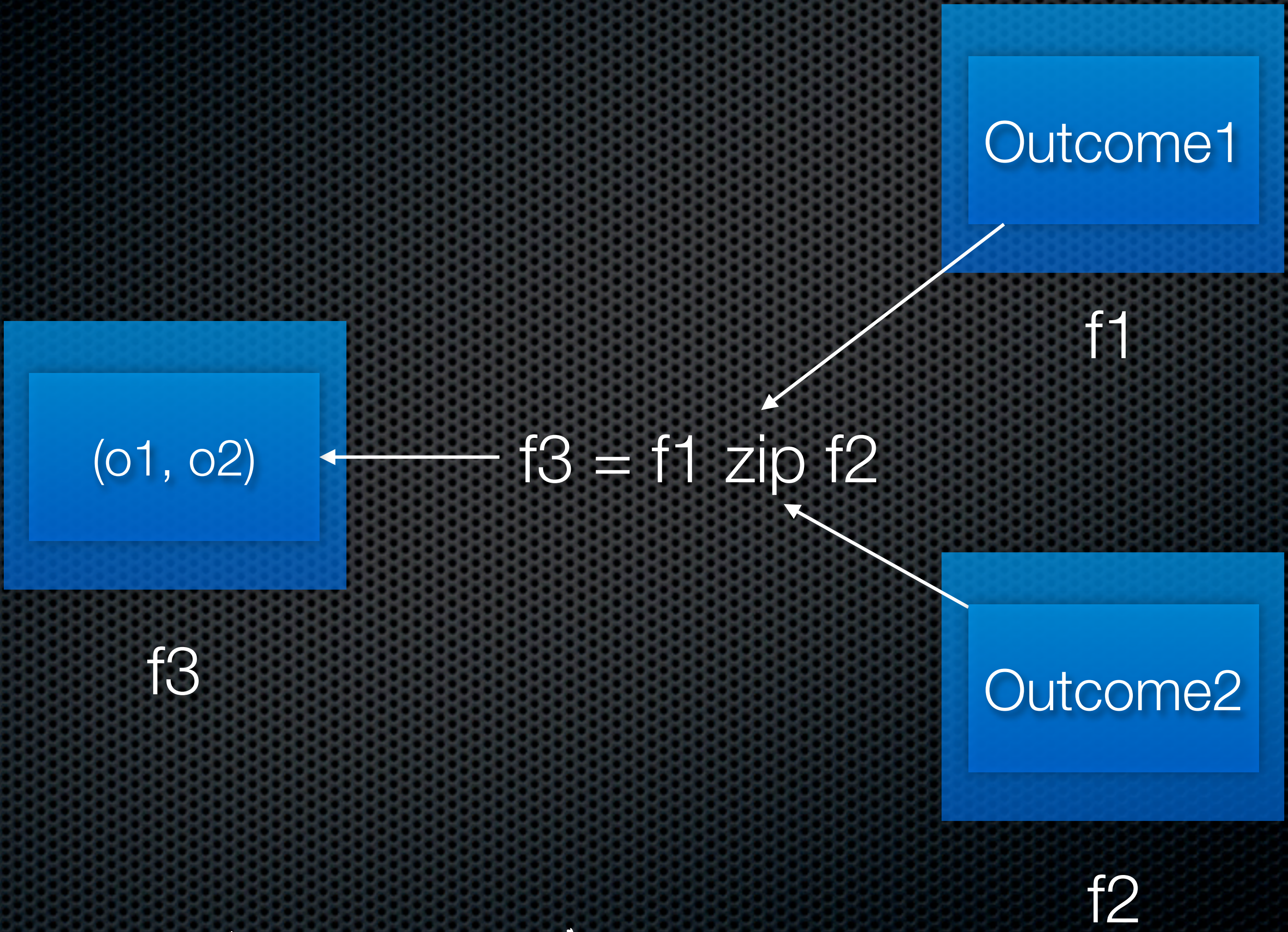
Combines two futures

```
val fzip = asyncSquare(5) zip asyncSquare(7)
assertEquals((25, 49), Await.result(fzip, 1 second))


val fseq = Future.sequence((1 to 5).map { x =>
              asyncSquare(x)
})

assertEquals(List(1, 4, 9, 16, 25),
             Await.result(fseq, 1 second))
```

Transforms list of futures to a future

Scala, Java 8 CompletableFuture (partially)

zip() is asynchronous



Implemented using callbacks

Transforming futures

```
def asyncPlus(x : Int, y : Int) = ... x + y ...

val future2 = asyncPlus(4, 5).map{ _ * 3 }

assertEquals(27, Await.result(future2, 1 second))
```

Asynchronously transforms future

Scala, Java 8 CompletableFuture (partially)

Chaining asynchronous operations

Calls asyncSquare() with the eventual outcome of asyncPlus()

```
val f2 = asyncPlus(5, 8).flatMap { x => asyncSquare(x) }

assertEquals(169, Await.result(f2, 1 second))
```

Scala, Java 8 CompletableFuture (partially)

Scala futures are Monads

Two calls execute in parallel

```
(asyncPlus(3, 5) zip asyncSquare(5))
  .flatMap {
      case (a, b) =>
       asyncPlus(a, b) map { _ * 2 }
  }

result onSuccess { .... }
```

And then invokes asyncPlus()

x 2

Rewrite using 'for'

Scala futures are Monads

```
val result = for {
  (a, b) <- asyncPlus(3, 5) zip asyncSquare(5);
  c <- asyncPlus(a, b)
} yield c * 2

result onSuccess { .... }
```

Two calls execute in parallel

And then invokes asyncPlus()

x 2

'for' is shorthand for map() and flatMap()

ProductInfoService: using Scala Futures

```
import scala.concurrent.Future

@Component
class ProductInfoService {

  def getProductInfo(productId: Long): Future[ProductInfo]
    = {
    Future { restTemplate.getForObject(....) }
  }

}
```

Scala Future

Executed in a threaded pool

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ProductDetailsService: using Scala Futures

Return a Scala Future

```
class ProductDetailsService ...


  def getProductDetails(productId: Long) : Future[ProductDetails] = {
    val productInfoFuture = productInfoService.getProductInfo(productId)
    val recommendationsFuture =
                  recommendationService.getRecommendations(productId)
    val reviewsFuture = reviewService.getReviews(productId)

    for (((productInfo, recommendations), reviews) <-
             productInfoFuture zip recommendationsFuture zip reviewsFuture)
          yield ProductDetails(productInfo, recommendations, reviews)


  }
}
```

Gathers data without blocking

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Async ProductController: using Spring MVC DeferredResult

```
@Controller
class ProductController ... {

  @RequestMapping(Array("/productdetails/{productId}"))
  @ResponseBody
  def productDetails(@PathVariable productId: Long)
                  : DeferredResult[ProductDetails] = {
    val productDetails =
          productDetailsService.getProductDetails(productId)
    val result = new DeferredResult[ProductDetails]
     productDetails onSuccess {
       case r => result.setResult(r)
     }
     productDetails onFailure {
       case t => result.setErrorResult(t)
     }
    result
  }
```

Spring MVC
DeferredResult
≅
Future

Convert Scala Future
to
DeferredResult

Servlet layer is asynchronous

BUT

the backend uses thread pools

⇒

Need event-driven REST client

Spring AsyncRestTemplate

- New in Spring 4
- Mirrors RestTemplate
- Can use HttpComponents NIO-based AsyncHttpClient
- Methods return a ListenableFuture
  - JDK 7 Future + callback methods

Yet another "Future"!

ProductInfoService: using the AsyncRestTemplate

```
class ProductInfoService {
 val asyncRestTemplate = new AsyncRestTemplate(
        new HttpComponentsAsyncClientHttpRequestFactory())


 override def getProductInfo(productId: Long) = {

  val listenableFuture =
   asyncRestTemplate.getForEntity("{baseUrl}/productinfo/{productId}",
                    classOf[ProductInfo],
                    baseUrl, productId)

   toScalaFuture(listenableFuture).map { _.getBody  }
 }
```

Convert to Scala Future and get entity

http://hc.apache.org/httpcomponents-asyncclient-dev/

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Converting ListenableFuture to Scala Future

```
def toScalaFuture[T](lf : ListenableFuture[T]) :
                                        Future[T] = {
    val p = promise[T]()

    lf.addCallback(new ListenableFutureCallback[T] {
      def onSuccess(result: T) { p.success(result)}
      def onFailure(t: Throwable) { p.failure(t)  }
    })
    p.future
  }
```

Creates a promise = producer API

Propagate outcome to promise

Return future

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Now everything is non-blocking :-)

We have achieved scaling Nirvana

WT*#*# is my code doing?

- Operations initiated in one thread but fail in another
  - Lack of a full stack trace can make debugging difficult
  - Inherent problem of async/event driven programming
- Futures make it very easy to forget to handle errors
  - `someFuture.foreach { handleTheHappyPath }`
  - Error is quietly ignored: similar to an empty catch {} block

Agenda

- The need for concurrency
- Simplifying concurrent code with Futures
- Consuming asynchronous streams with Reactive Extensions

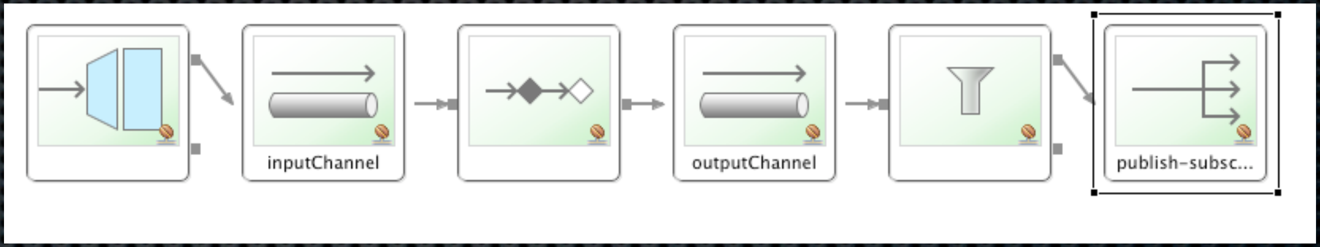
Let’s imagine you have a stream of trades
and
you need to calculate the 15 minute rolling average price of each stock

Where is the high-level abstraction that simplifies solving this problem?

Future[List[T]]

Not applicable to infinite streams

Pipes and Filters
e.g. Spring Integration
+
Complex event processing (CEP)



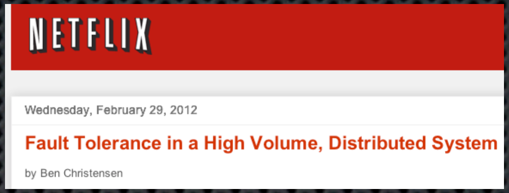
Not bad but tends to be an external DSL, heavy weight, statically defined, ...

Introducing Reactive Extensions (Rx)

The Reactive Extensions (Rx) is a library for composing asynchronous and event-based programs using observable sequences and LINQ-style query operators. Using Rx, developers **represent asynchronous data streams with Observables** , **query asynchronous data streams using LINQ operators** , and .....

https://rx.codeplex.com/

About RxJava


NETFLIX

Wednesday, February 29, 2012

Fault Tolerance in a High Volume, Distributed System

by Ben Christensen

- Reactive Extensions (Rx) for the JVM
- Original motivation for Netflix was to provide rich Futures
- Implemented in Java
- Adaptors for Scala, Groovy and Clojure

https://github.com/Netflix/RxJava

RxJava core concepts

An asynchronous stream of items

```
trait Observable[T] {
  def subscribe(observer : Observer[T]) : Subscription
  ...
}
```

Notifies

```
trait Observer[T] {
  def onNext(value : T)
  def onCompleted()
  def onError(e : Throwable)
}
```

Used to unsubscribe

Comparing Observable to...

- Observer pattern - similar but adds
  - Observer.onComplete()
  - Observer.onError()
- Iterator pattern - mirror image
  - Push rather than pull
- Future - similar but
  - Represents a stream of **multiple** values

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So what?

Fun with observables

```
val oneItem = Observable.items(-1L)

val every10Seconds = Observable.interval(10 seconds)

val ticker = oneItem ++ every10Seconds

val subscription = ticker.subscribe ( new Observer[Long] {
  override def onNext(value: Long) = {  println("value=" + value)    }
})
...
subscription.unsubscribe()
```

-1	0	1	...
t=0	t=10	t=20	...

Creating observables

```
Observable.create({ observer: Observer[T] =>
    ...
    observer.onNext(...)
    ...
    observer.onCompleted()
    ...
    observer.onError(...)
    ...
   Subscription{ .... }
   }
 })
```

Function called when Observer subscribes

Called when observer unsubscribes

Creating observables from Scala Futures

Query AWS

```
def getTableStatus(tableName: String) = {
  val future = dynamoDbClient.describeTable(new DescribeTableRequest(tableName))

  Observable.create({ observer.onNext: Observer[DynamoDbStatus] =>
    future.onComplete {
      case Success(response) =>
        observer.onNext(DynamoDbStatus(response.getTable.getTableStatus))
        observer.onCompleted()

      case Failure(t: ResourceNotFoundException) =>
        observer.onNext(DynamoDbStatus("NOT_FOUND"))
        observer.onCompleted()

      case Failure(someError) =>
        observer.onError(someError)

    }
    Subscription({})
  })
}
```

Propagate outcome

Transforming observables

```
val tableStatus = ticker.flatMap { i =>
    logger.info("{}th describe table", i + 1)
    getTableStatus(name)
}
```

Status1	Status2	Status3	...
t=0	t=10	t=20	...

+ Usual collection methods: map(), filter(), take(), drop(), ...

Back to the stream of Trades averaging example...

Calculating averages

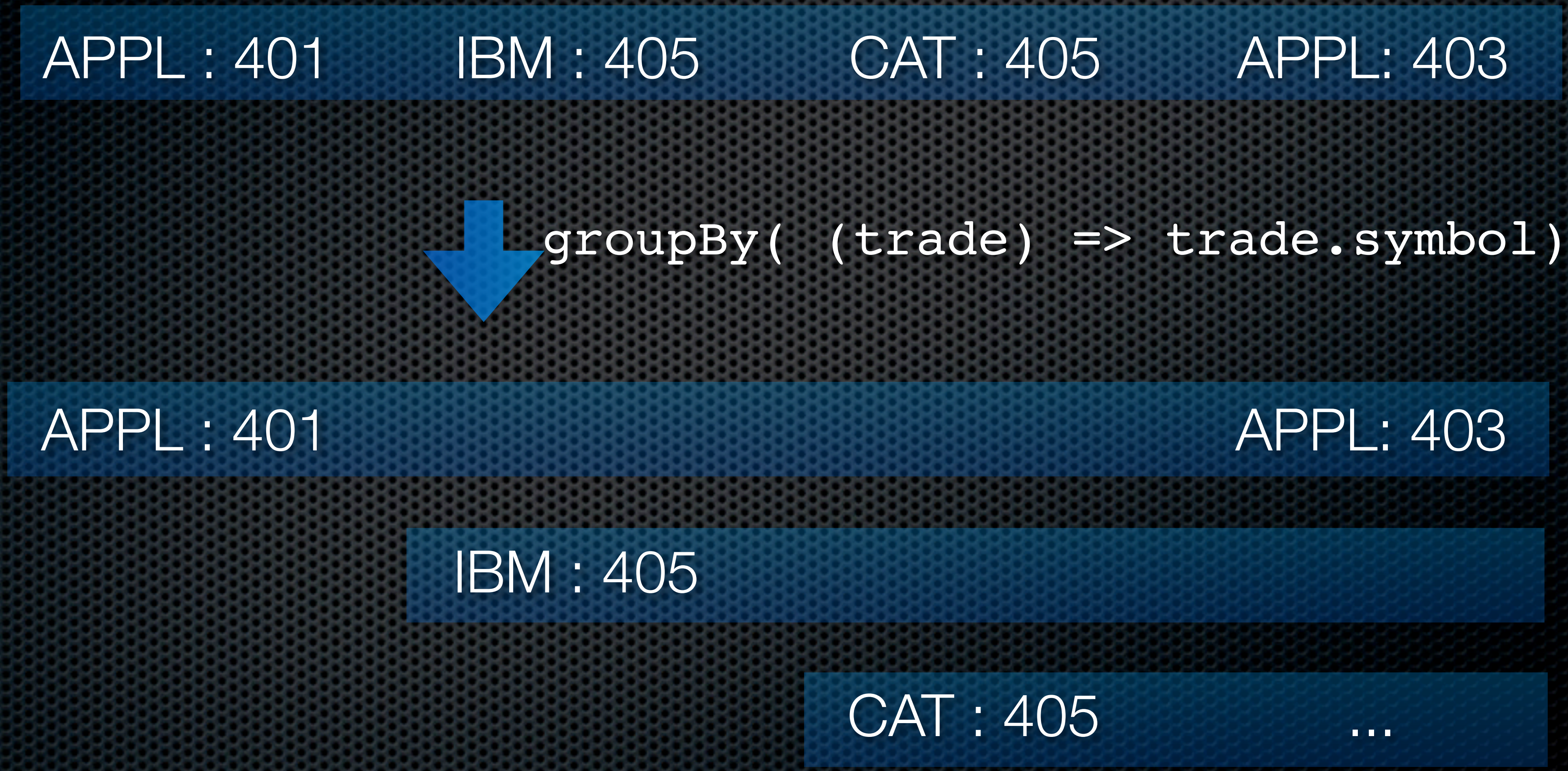
```
class AverageTradePriceCalculator {

  def calculateAverages(trades: Observable[Trade]):
      Observable[AveragePrice] = {
    ...
  }
```

```
case class Trade(
 symbol : String,
 price : Double,
 ...
)
```

```
case class AveragePrice(
  symbol : String,
  price : Double,
  ...)
```

Using groupBy()

```
Observable[Trade]
```



```
groupBy( (trade) => trade.symbol)
```

```
Observable[GroupedObservable[String, Trade]]
```

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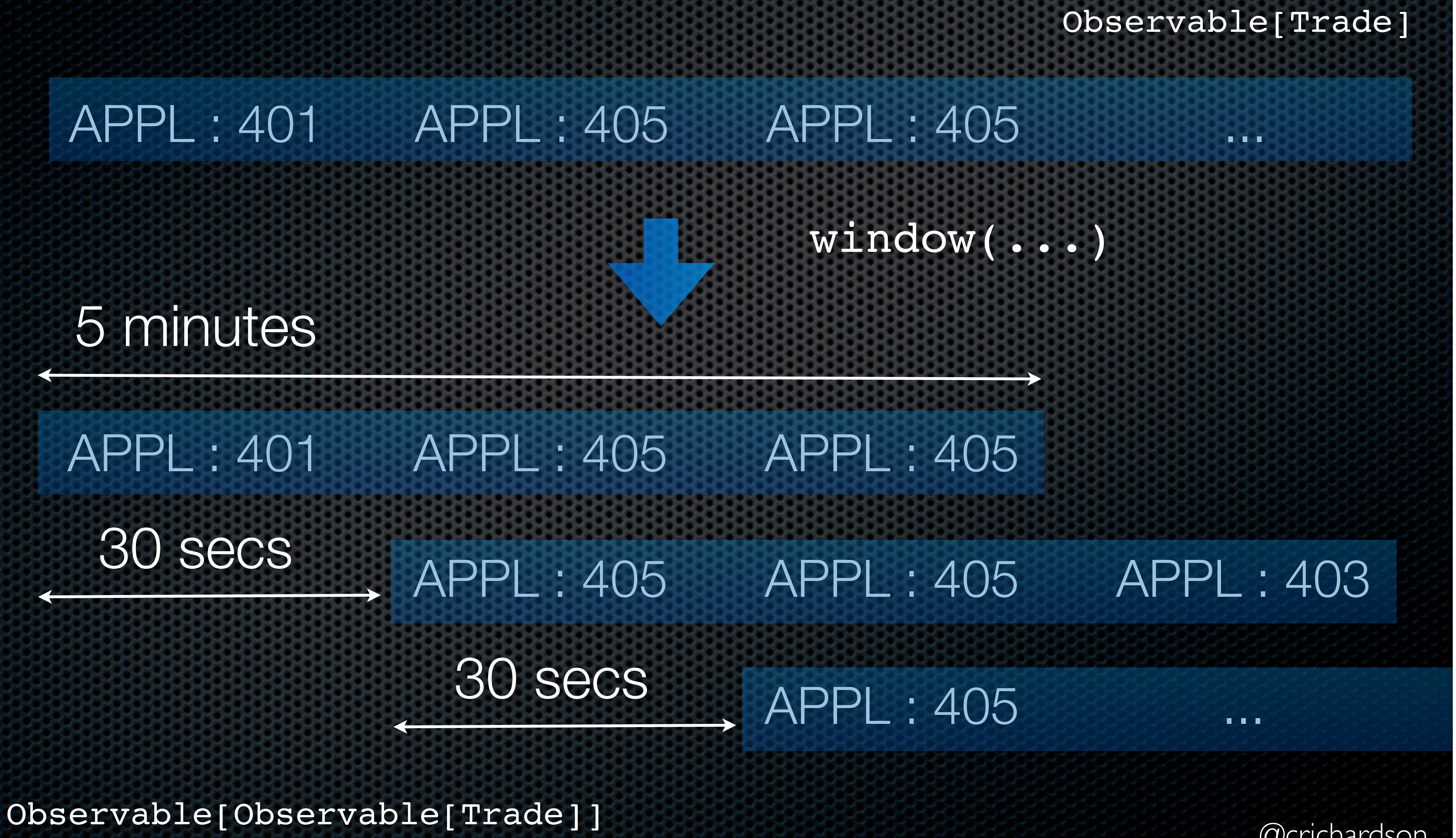
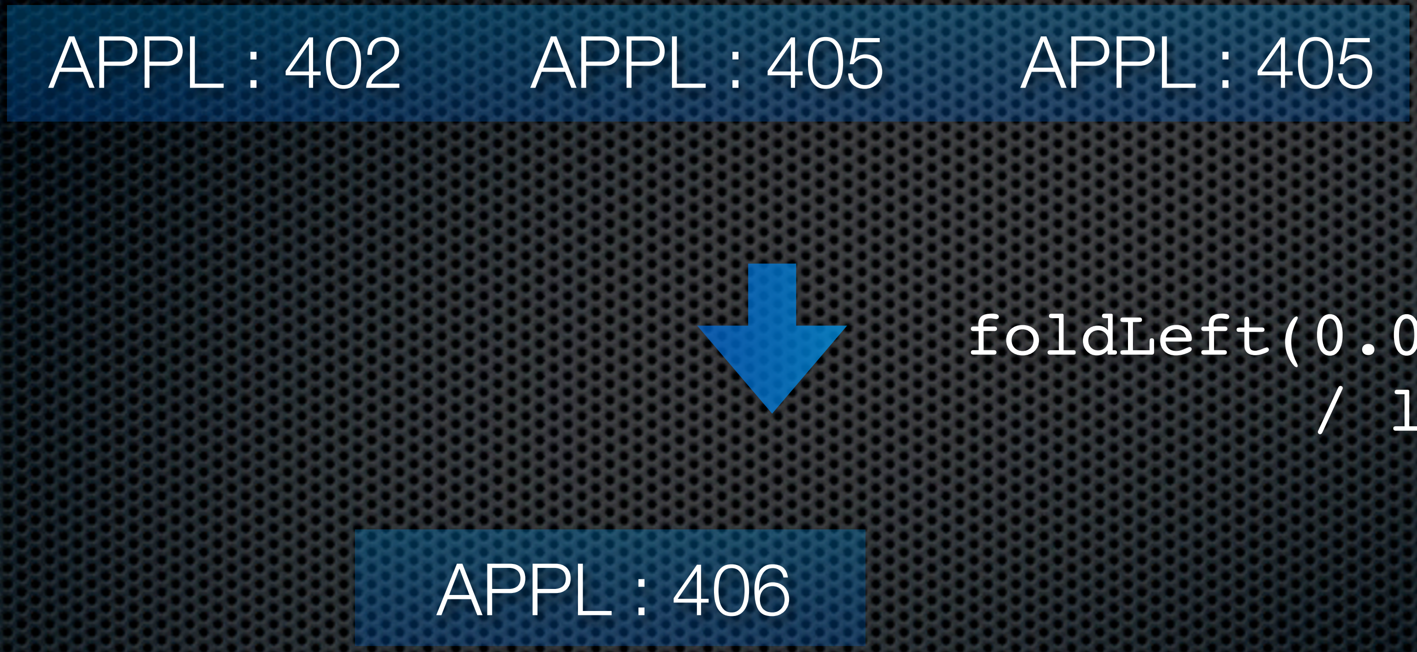
Using window()



Using foldLeft()

`Observable[Trade]`

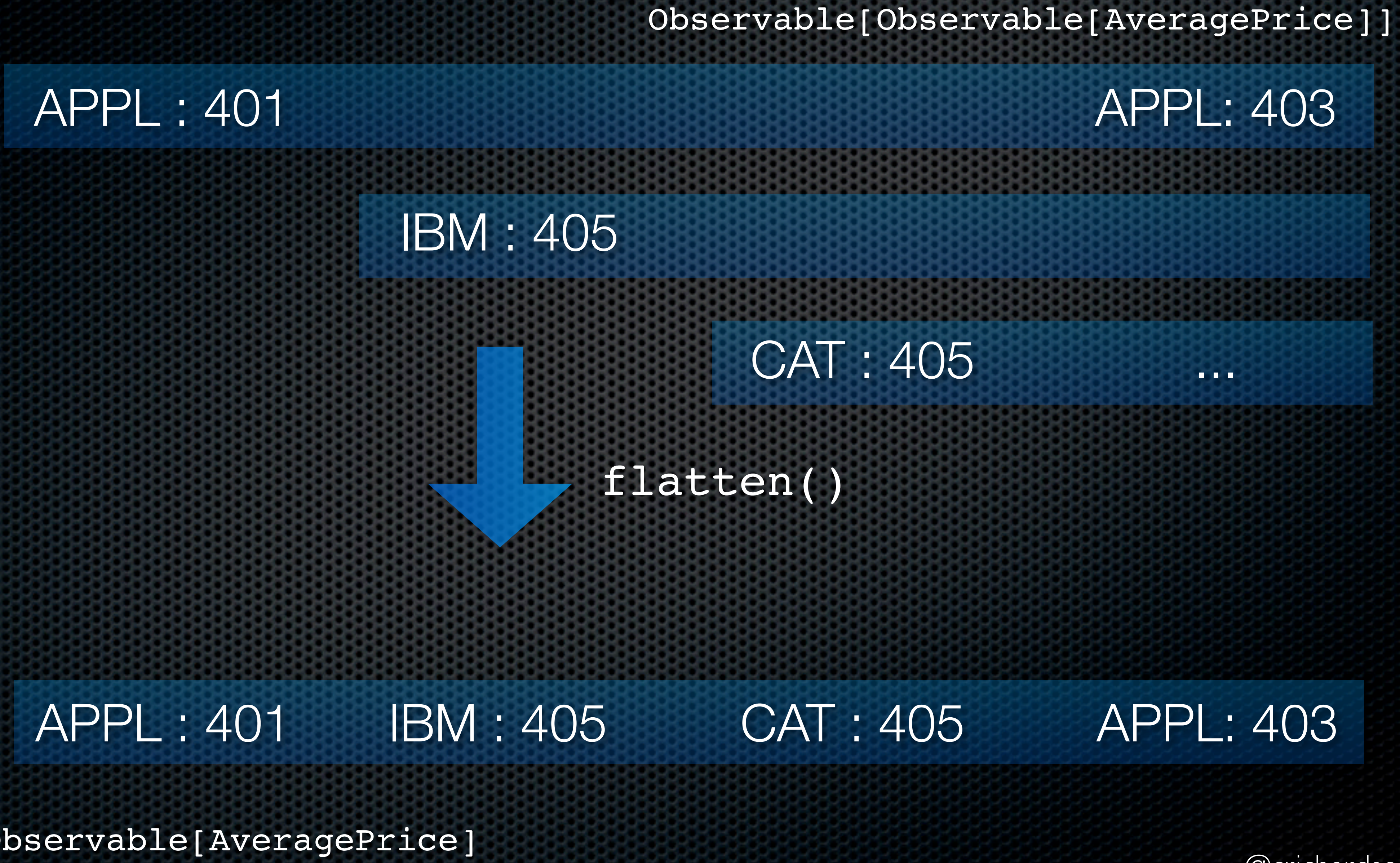


```
foldLeft(0.0)(_ + _.price)
        / length
```

`Observable[AveragePrice]`

Singleton

Using flatten()



Calculating average prices

```
def calculateAverages(trades: Observable[Trade]): Observable[AveragePrice] = {

  trades.groupBy(_.symbol).map { symbolAndTrades =>
    val (symbol, tradesForSymbol) = symbolAndTrades
      val openingEverySecond =
           Observable.items(-1L) ++ Observable.interval(1 seconds)
      def closingAfterSixSeconds(opening: Any) =
          Observable.interval(6 seconds).take(1)

    tradesForSymbol.window(...).map {
      windowOfTradesForSymbol =>
        windowOfTradesForSymbol.fold((0.0, 0, List[Double]())) { (soFar, trade) =>
           val (sum, count, prices) = soFar
          (sum + trade.price, count + 1, trade.price +: prices)
        } map { x =>
            val (sum, length, prices) = x
            AveragePrice(symbol, sum / length, prices)
        }
    }.flatten
  }.flatten
}
```

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Summary

- Consuming web services asynchronously is essential
- Scala-style Futures are a powerful concurrency abstraction
- Rx Observables
    - even more powerful
    - unifying abstraction for a wide variety of use cases

@crichardson chris@chrisrichardson.net

Questions?

http://plainoldobjects.com