Dr Streamlove

or: How I Learned to Stop Worrying and Love the Flow

Viktor Klang
Chief Architect
@viktorklang

Typesafe

Typesafe

- Founded ~3.5 years ago
  - fusion of Scalable Solutions and Scala Solutions
- Offices in Uppsala, Lausanne and San Francisco
- 60+ employees all over the world
- Main projects
  - Play, Akka, Scala, Slick

My office door

View from my office

Agenda

- What is a Stream?
- Live demo
- What is Reactive?
- Reactive Streams
- Akka Streams
- Live demo
- What's next / Opportunities
- Outro

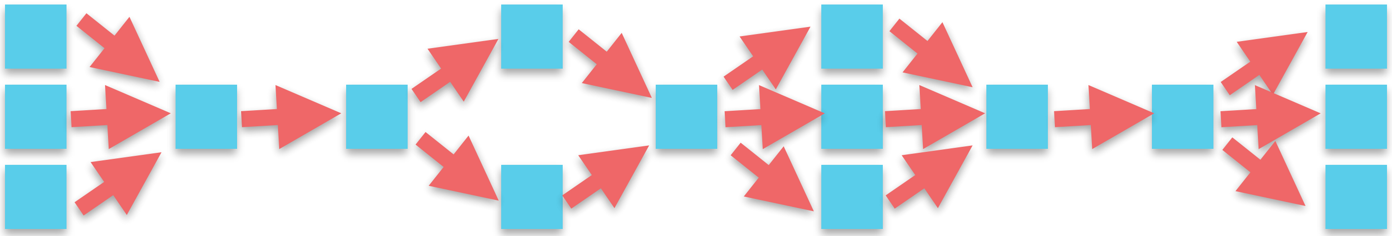
What do we mean by “Stream”?

*“You cannot step twice into the same stream.
For as you are stepping in,
other waters are ever flowing on to you.”*

- Heraclitus

What is a Stream?

- Ephemeral flow of data
- Possibly unbounded in length
- Focused on describing transformation
- Can be formed into processing networks



What is a Collection?

- Oxford Dictionary:
  - “a group of things or people”
- wikipedia:
  - “a grouping of some variable number of data items”
- backbone.js:
  - “collections are simply an ordered set of models”
- java.util.Collection:
  - definite size, provides an iterator, query membership

User Expectations

- an Iterator is expected to visit all elements
  (especially with immutable collections)
- `x.head ++ x.tail == x`
- the contents does not depend on who is processing the collection
- the contents does not depend on when the processing happens
  (especially with immutable collections)

Unexpected: observed sequence depends on

- when the subscriber subscribed to the stream
- whether the subscriber can process fast enough
- whether the streams flows fast enough

java.util.stream

- Stream is not *derived* from Collection
  “Streams differ from Collections in several ways”
  - no storage
  - functional in nature
  - laziness seeking
  - possibly unbounded
  - consumable

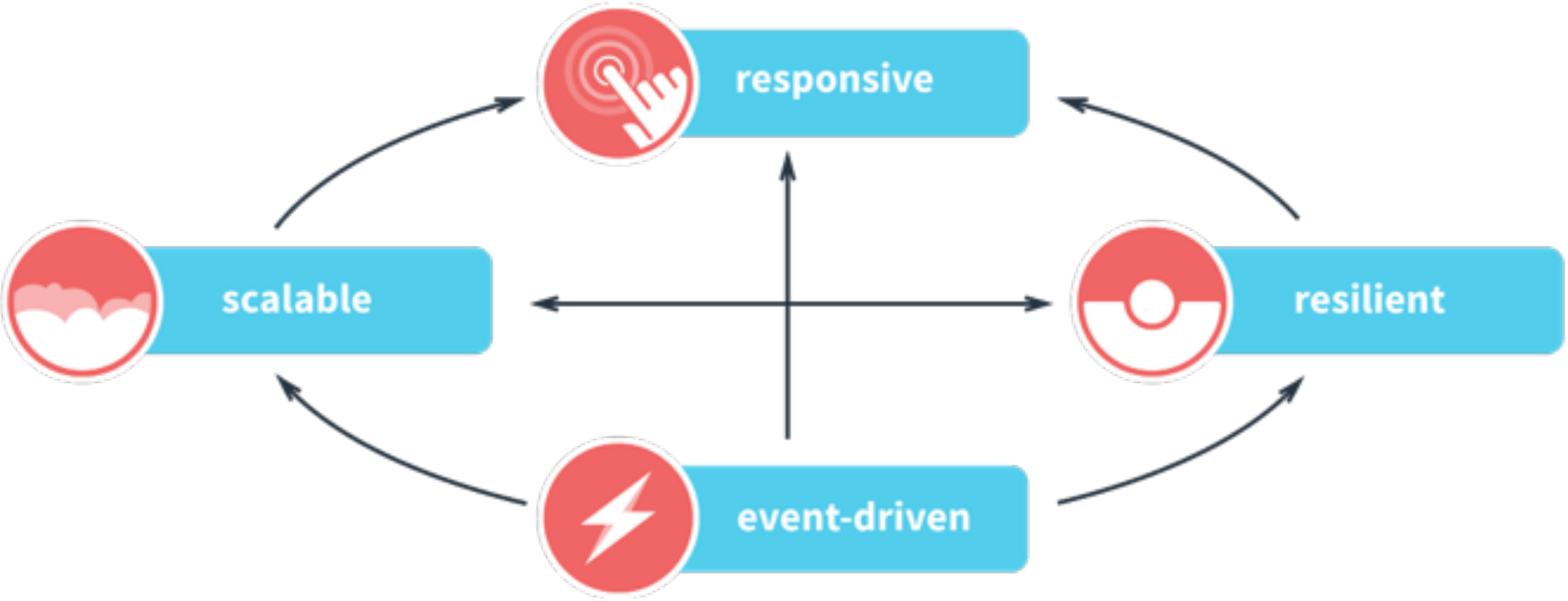
Streams vs. Collections

- a collection can be streamed
- a stream processor can create a collection
- … but saying that a Stream is just a lazy Collection evokes the wrong associations

Streams are *not* Collections!

Live Demo

The Four Horsemen of Reactive



http://reactivemanifesto.org/

The Problem:

Getting Data across an **Async Boundary**

Possible Solutions

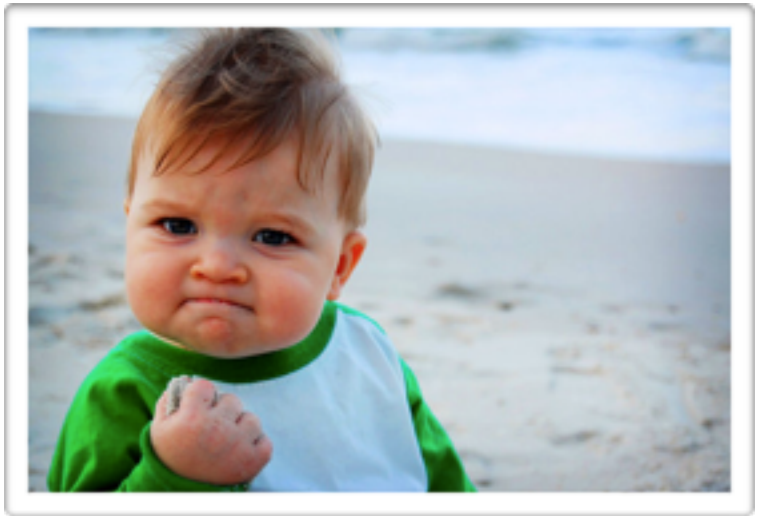
- the Traditional way: blocking calls

Possible Solutions

- the Push way: buffering and/or dropping

Possible Solutions

- the Reactive way:
  non-blocking & non-dropping & bounded



Reactive Streams Initiative

“Reactive Streams is an initiative to provide a standard for asynchronous stream processing with non-blocking back pressure on the JVM.”

- *reactive-streams.org*

Collaboration between Engineers

- Björn Antonsson – Typesafe Inc.
- Gavin Bierman – Oracle Inc.
- Jon Brisbin – Pivotal Software Inc.
- George Campbell – Netflix, Inc
- Ben Christensen – Netflix, Inc
- Mathias Doenitz – spray.io
- Marius Eriksen – Twitter Inc.
- Tim Fox – Red Hat Inc.
- Viktor Klang – Typesafe Inc.
- Dr. Roland Kuhn – Typesafe Inc.
- Doug Lea – SUNY Oswego
- Stephane Maldini – Pivotal Software Inc.
- Norman Maurer – Red Hat Inc.
- Erik Meijer – Applied Duality Inc.
- Todd Montgomery – Kaazing Corp.
- Patrik Nordwall – Typesafe Inc.
- Johannes Rudolph – spray.io
- Endre Varga – Typesafe Inc.

Motivation

- all participants face the same basic problem
- all are building tools for their community
- a common solution benefits everybody
- interoperability to make best use of efforts
  - e.g. use Reactor data store driver with Akka transformation pipeline and Rx monitoring to drive a vert.x REST API (purely made up, at this point)
- propose to include in future JDK

See also: Jon Brisbin’s post on “Tribalism as a Force for Good”

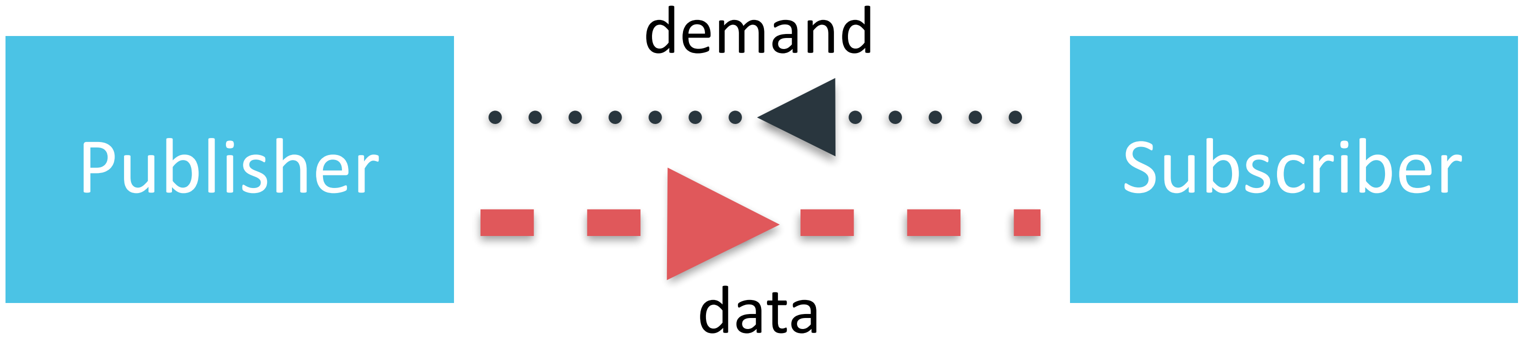
Recipe for Success

- minimal interfaces—essentials only
- rigorous specification of semantics
- TCK for verification of implementation
- complete freedom for many idiomatic APIs

Reactive Streams

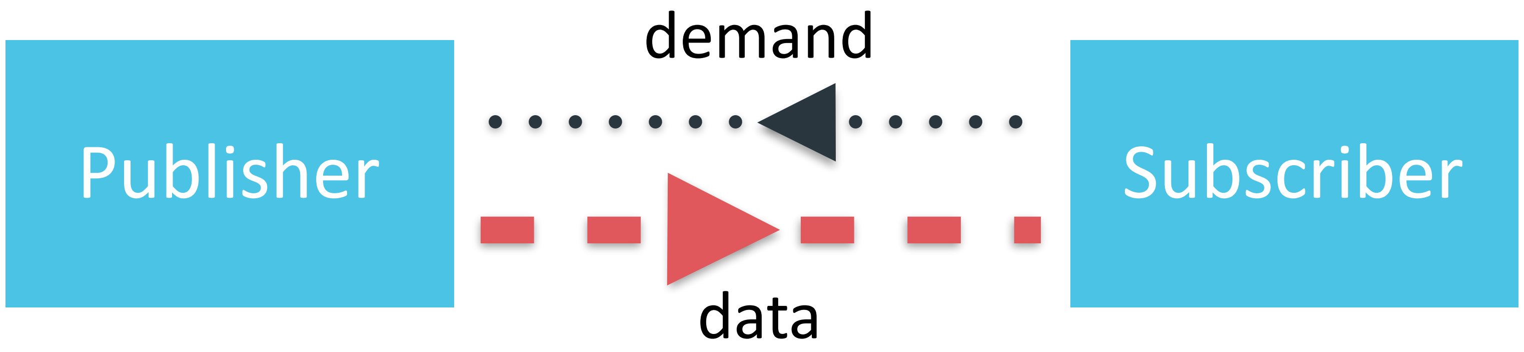
- asynchronous & non-blocking
    - flow of data
    - flow of demand
- minimal coordination and contention
- message passing allows for distribution across
    - applications, nodes, CPUs, threads, actors

A Data Market using Supply & Demand



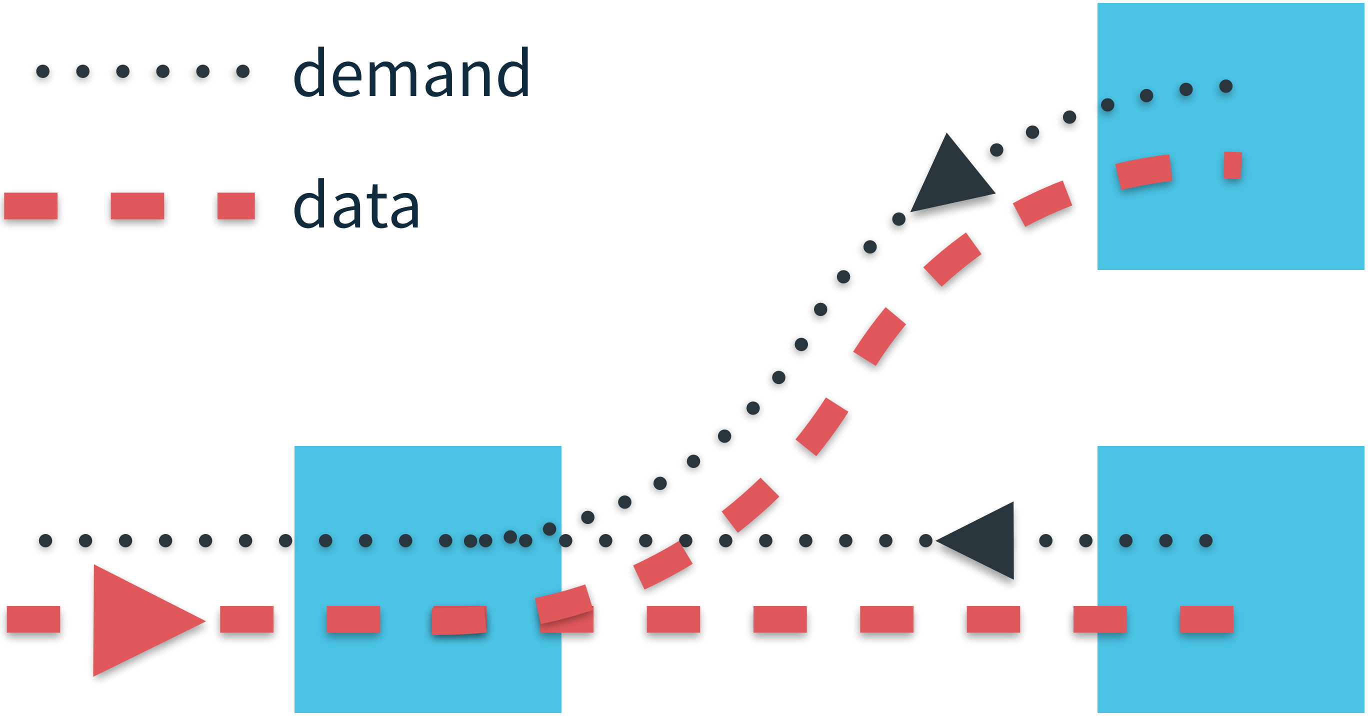
- data elements flow downstream
- demand flows upstream
- data elements flow only when there is demand
    - data in flight is bounded by signaled demand
    - recipient is in control of maximal incoming data rate

Dynamic Push–Pull



- “push”—when consumer is faster
- “pull”—when producer is faster
- switches automatically between these
- batching demand allows batching data

Explicit Demand: One-to-many

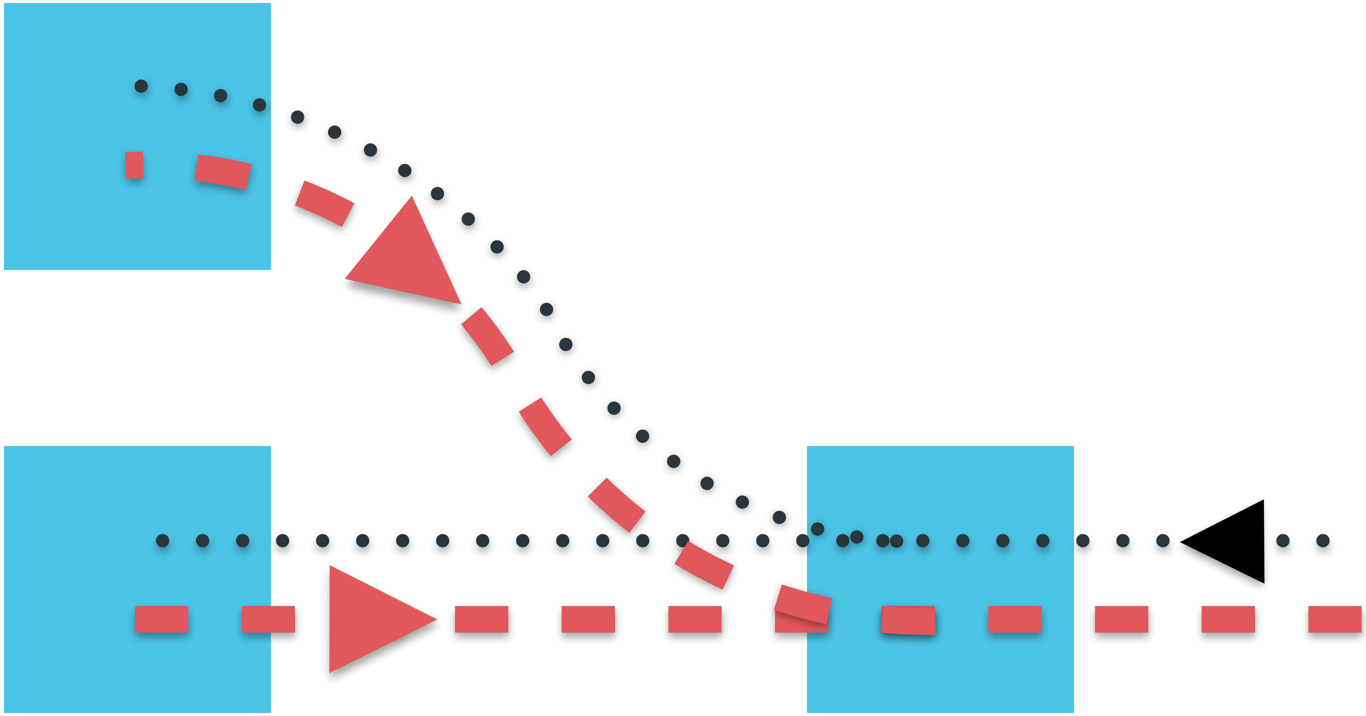


• • • • • • demand

▬ ▬ ▬ data

Splitting the data means *merging the demand*

Explicit Demand: Many-to-one



Merging the data means *splitting the demand*

The Meat: Scala

```scala
trait Publisher[T] {
  def subscribe(sub: Subscriber[T]): Unit
}
trait Subscription {
  def request(n: Int): Unit
  def cancel(): Unit
}
trait Subscriber[T] {
  def onSubscribe(s: Subscription): Unit
  def onNext(e: T): Unit
  def onError(t: Throwable): Unit
  def onComplete(): Unit
}
```

The dessert: Scala

```
trait Processor[T, R] extends Subscriber[T]
                         with Publisher[R]
```

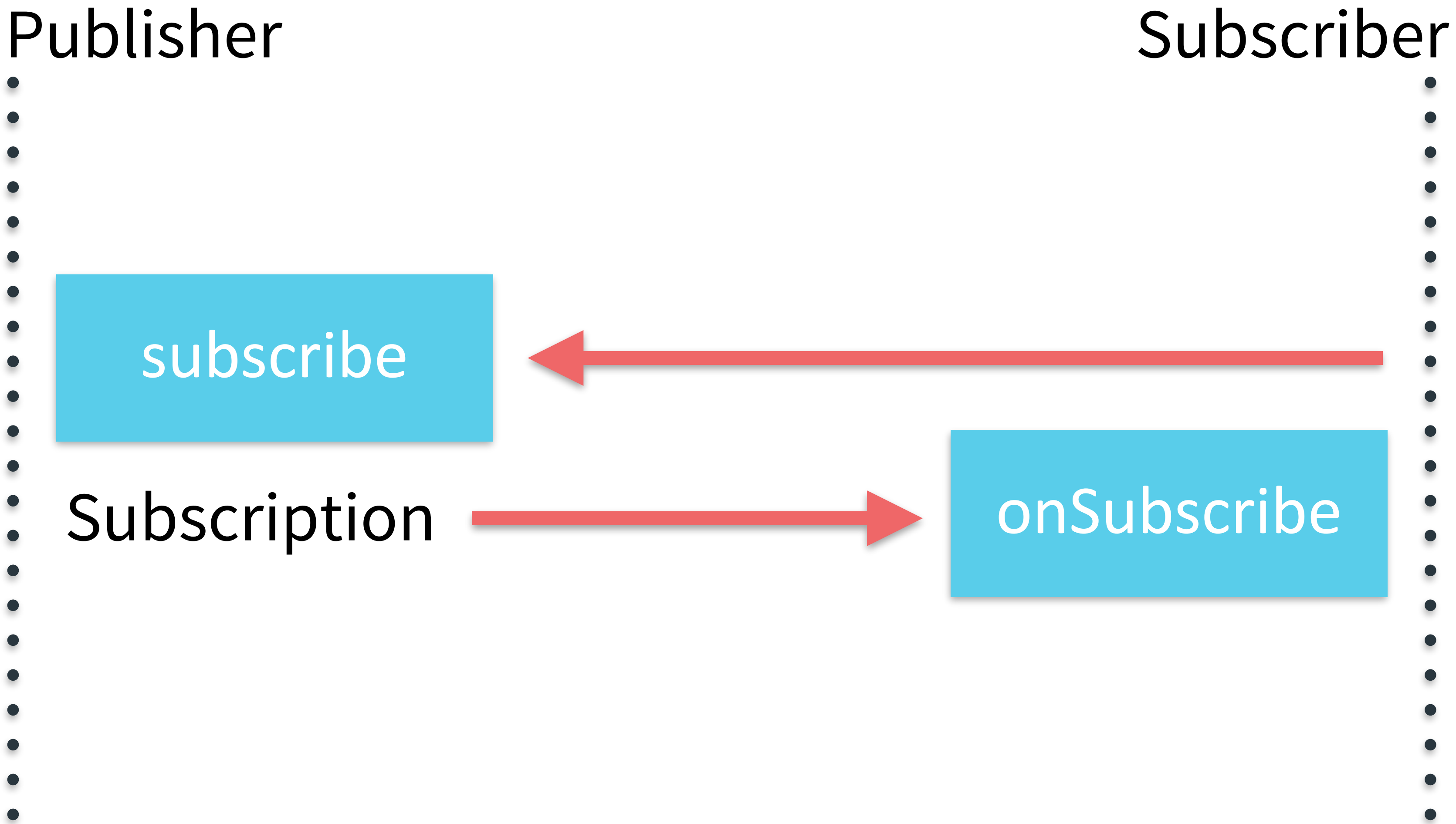
The Meat: Java

```
public interface Publisher<T> {
  public void subscribe(Subscriber<T> s);
}
public void Subscription {
  public void request(Int n);
  public void cancel();
}
public interface Subscriber<T> {
  public void onSubscribe(Subscription s);
  public void onNext(T t);
  public void onError(Throwable t);
  public void onComplete();
}
```

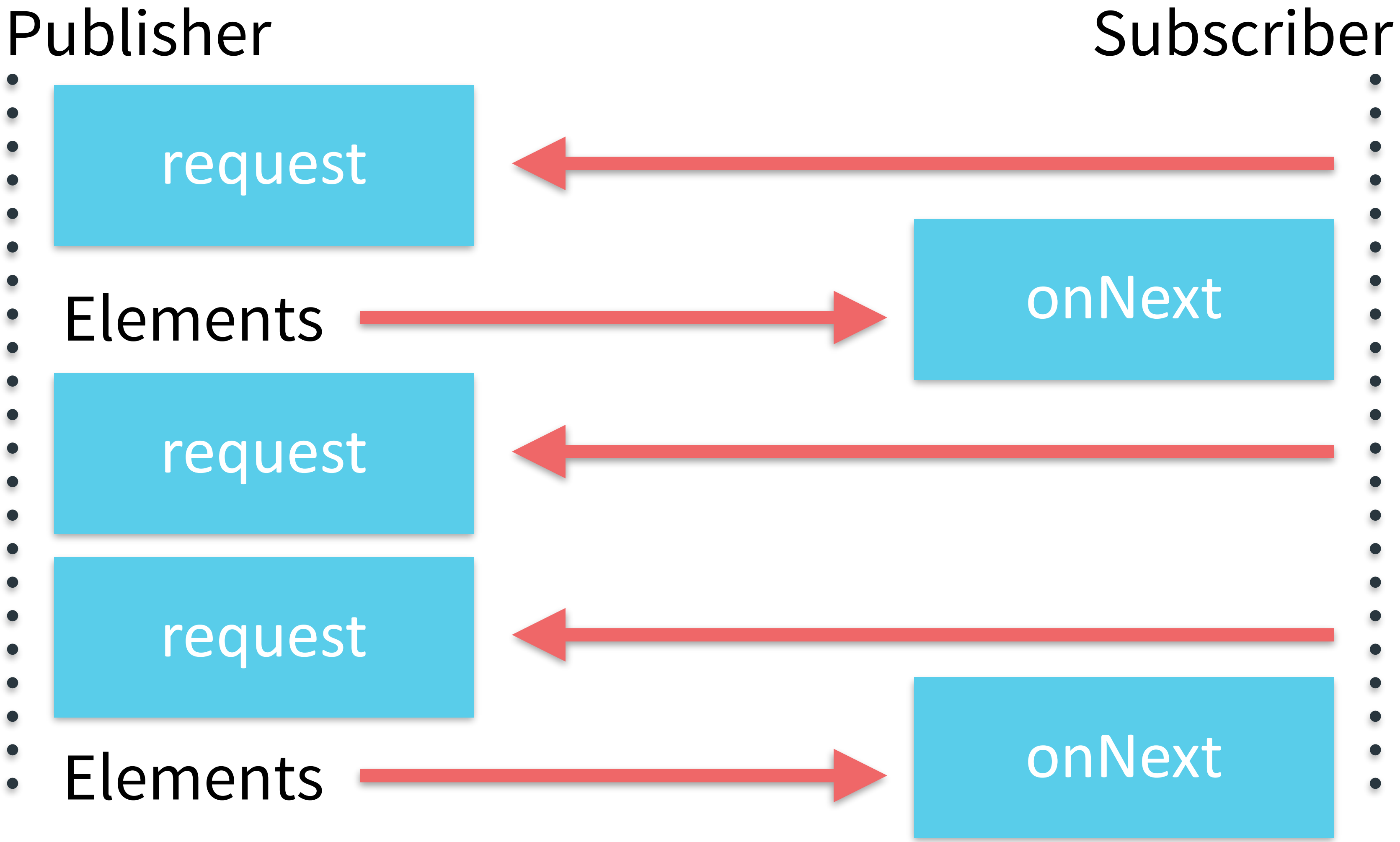
The dessert: Java

```
public interface Processor<T, R>
  extends Subscriber<T>, Publisher<R> {
}
```

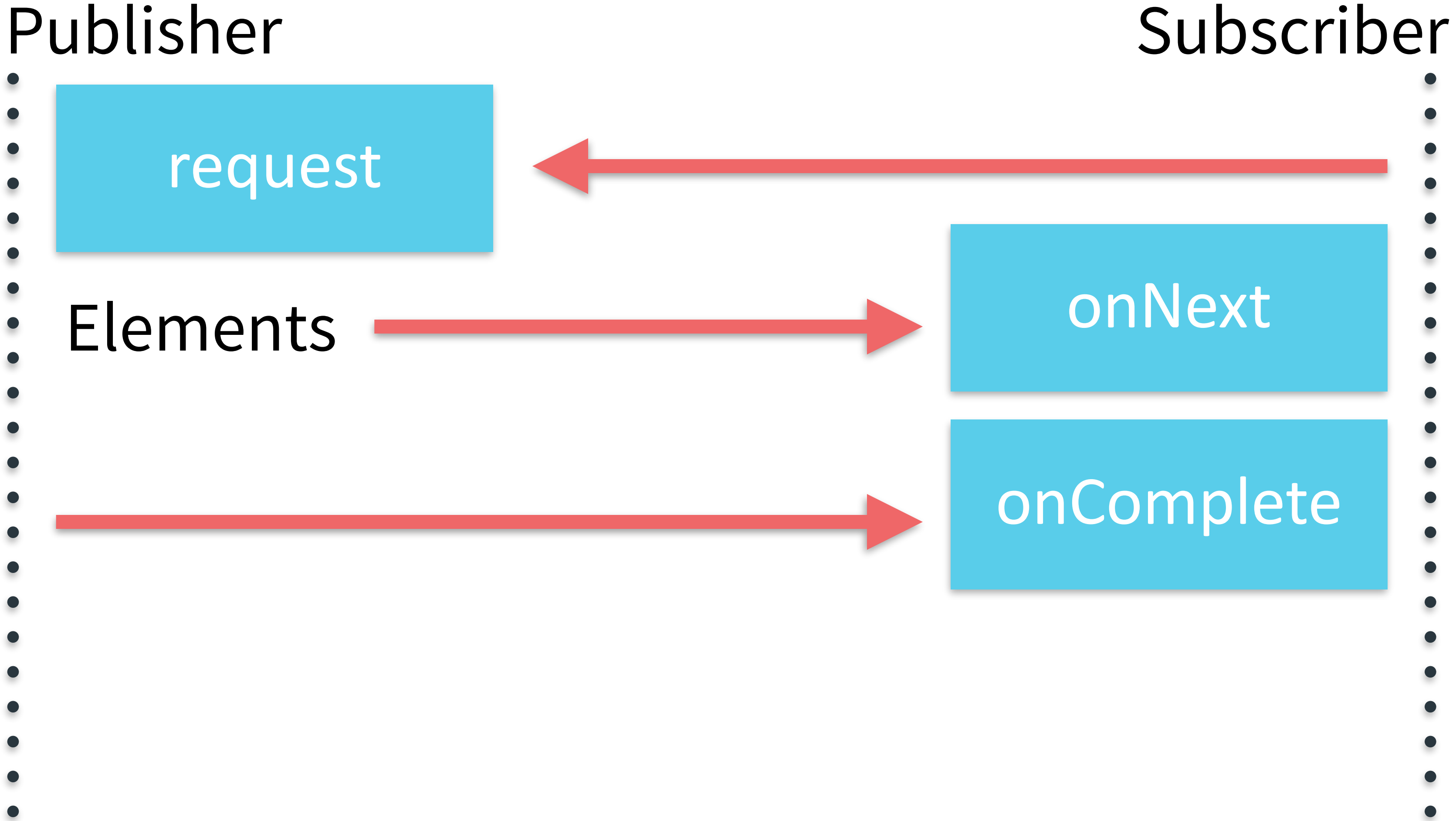
How does it Connect?



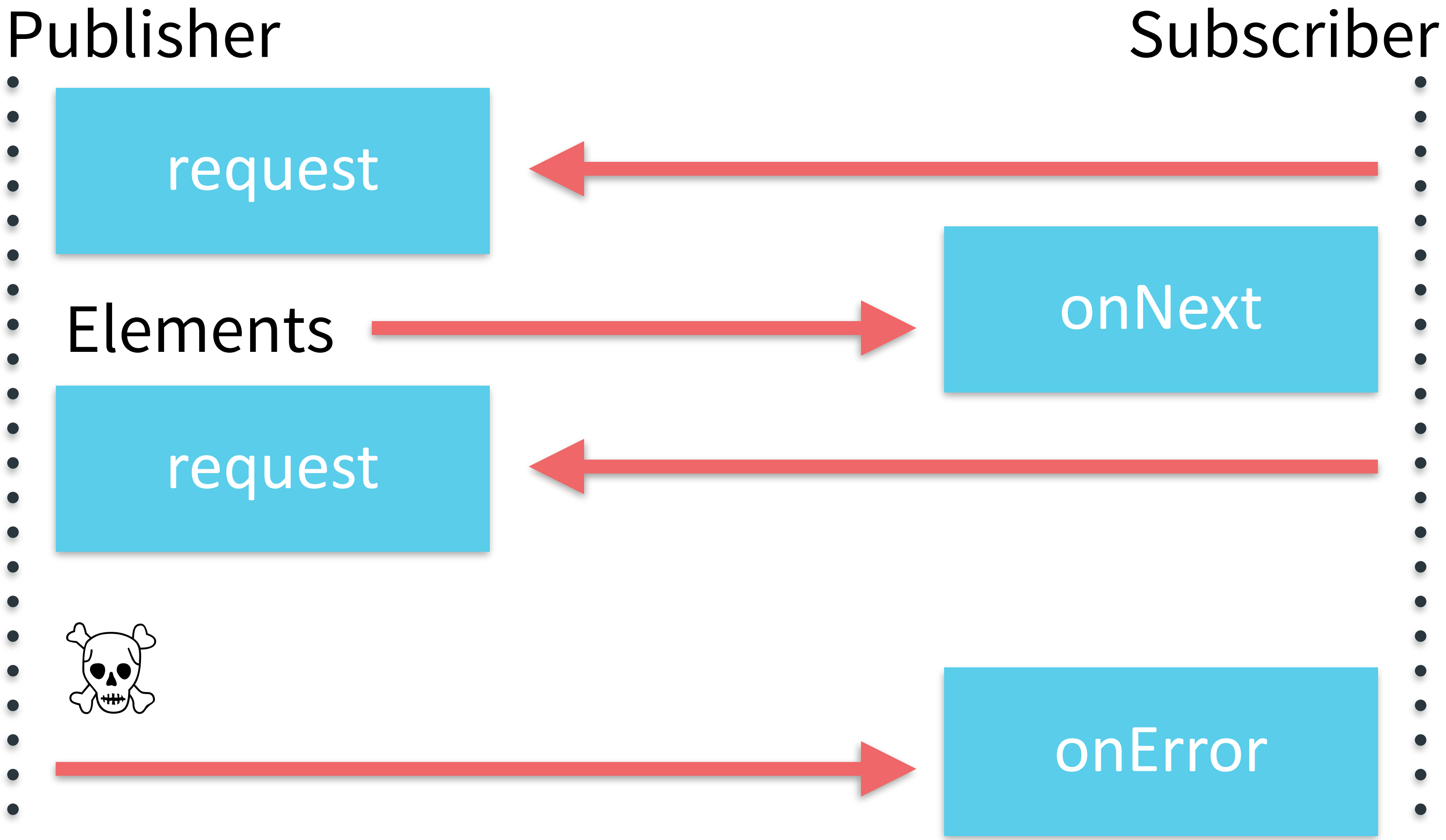
How does it Flow?



How does it Complete?



How does it Fail?



Akka Streams

WAIT! What is akka ?

1613 Turbo
P.R.

Akka

- Akka's unit of computation is called an Actor
- Akka Actors are purely reactive components:
  - an address
  - a mailbox
  - a current behavior
  - local storage
- Scheduled to run when sent a message
- Each actor has a parent, handling its failures
- Each actor can have 0..N “child” actors

Akka Actors

- An actor processes a message at a time
  - Multiple-producers & Single-consumer
- The overhead per actor is about ~450bytes
  - Run millions of actors on commodity hardware
- Akka Cluster currently handles ~2500 nodes
  - 2500 nodes × millions of actors
    =
    “ought to be enough for anybody”

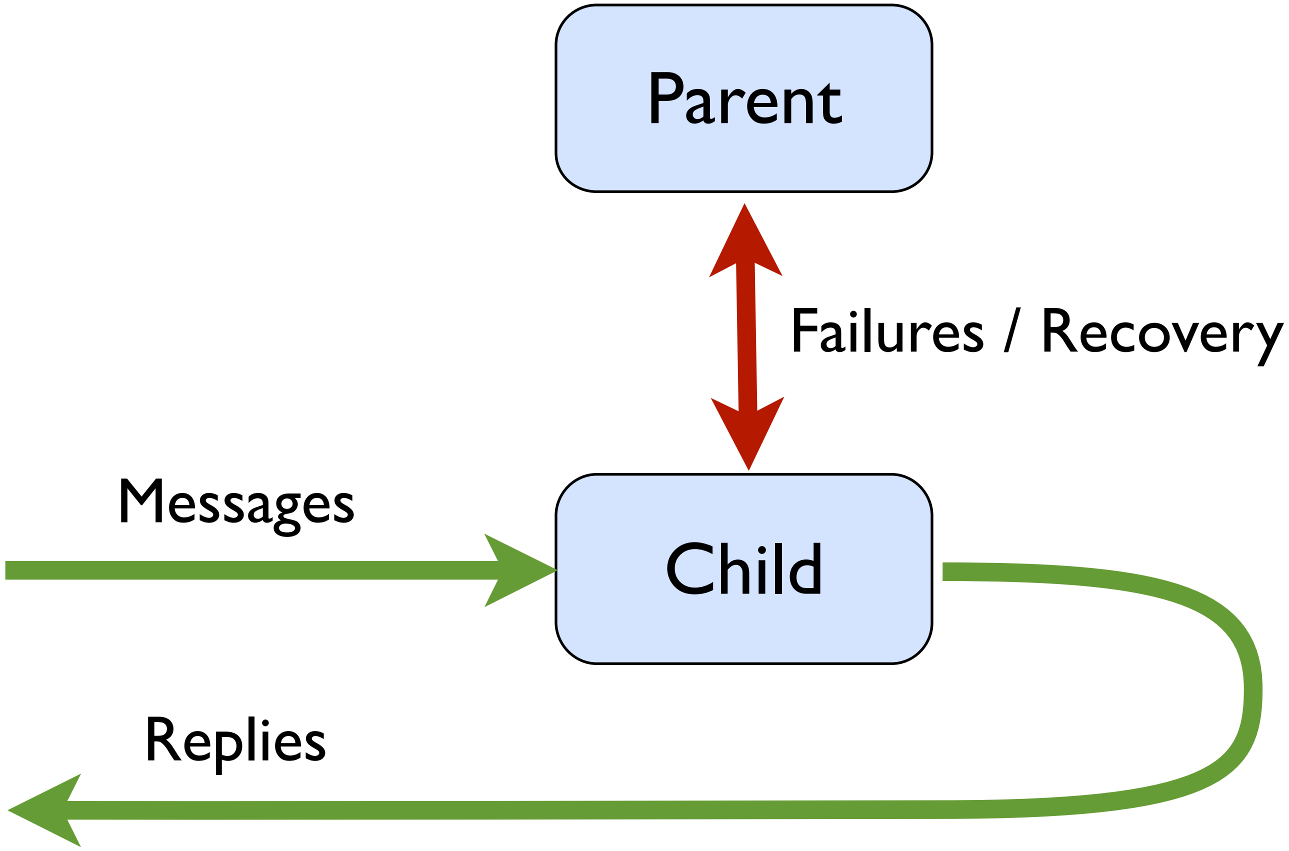
Actor model fundamentals

- **CREATE**(behavior)
  - Creates a new actor
- **BECOME**(behavior)
  - Changes the actors behavior for the next message
- **SEND**(message)
  - Sends a message asynchronously and non-blocking to an actor

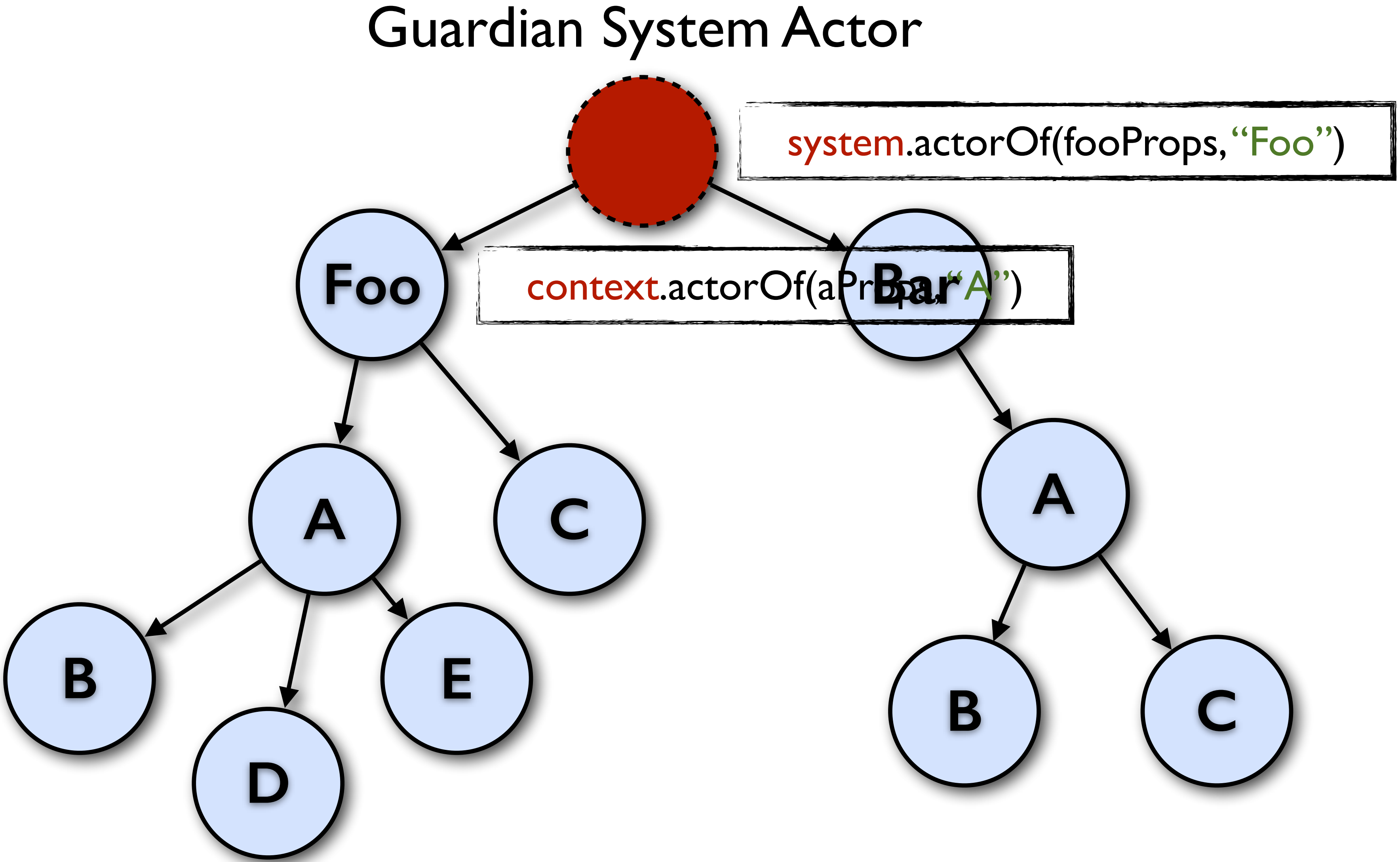
Actor model augmentations

- **SUPERVISE**(actor)
  - Lets an actor handle the failure(s) of another actor
- **WATCH**(actor)
  - Lets an actor observe the termination of another actor

Actor Messages vs Failures



Actor Hierarchies

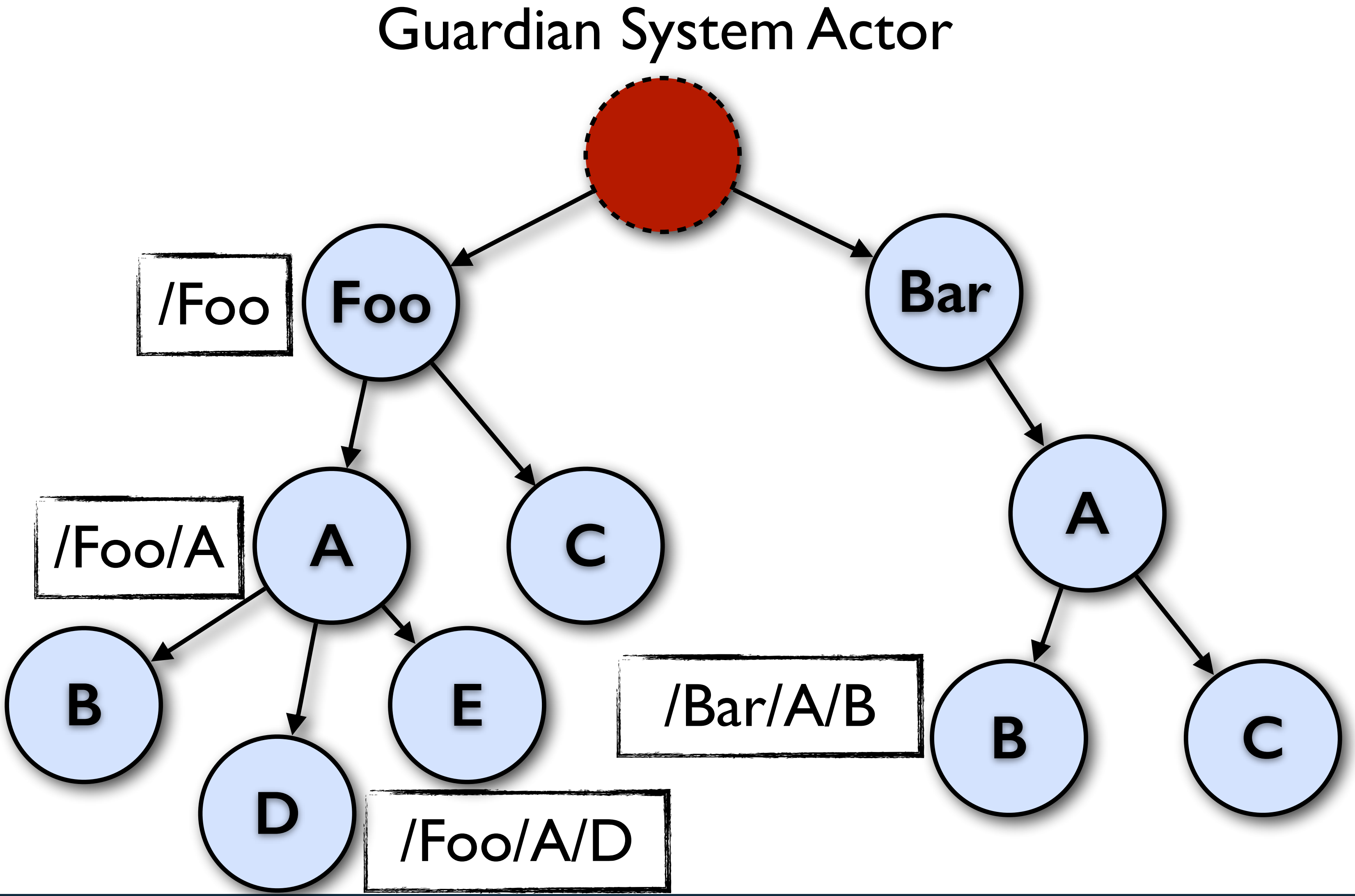


Guardian System Actor

system.actorOf(fooProps, “Foo”)

context.actorOf(aProps, “A”)

Actor Paths


Guardian System Actor
/Foo
Foo
Bar
/Foo/A
A
C
A
B
E
/Bar/A/B
B
C
D
/Foo/A/D

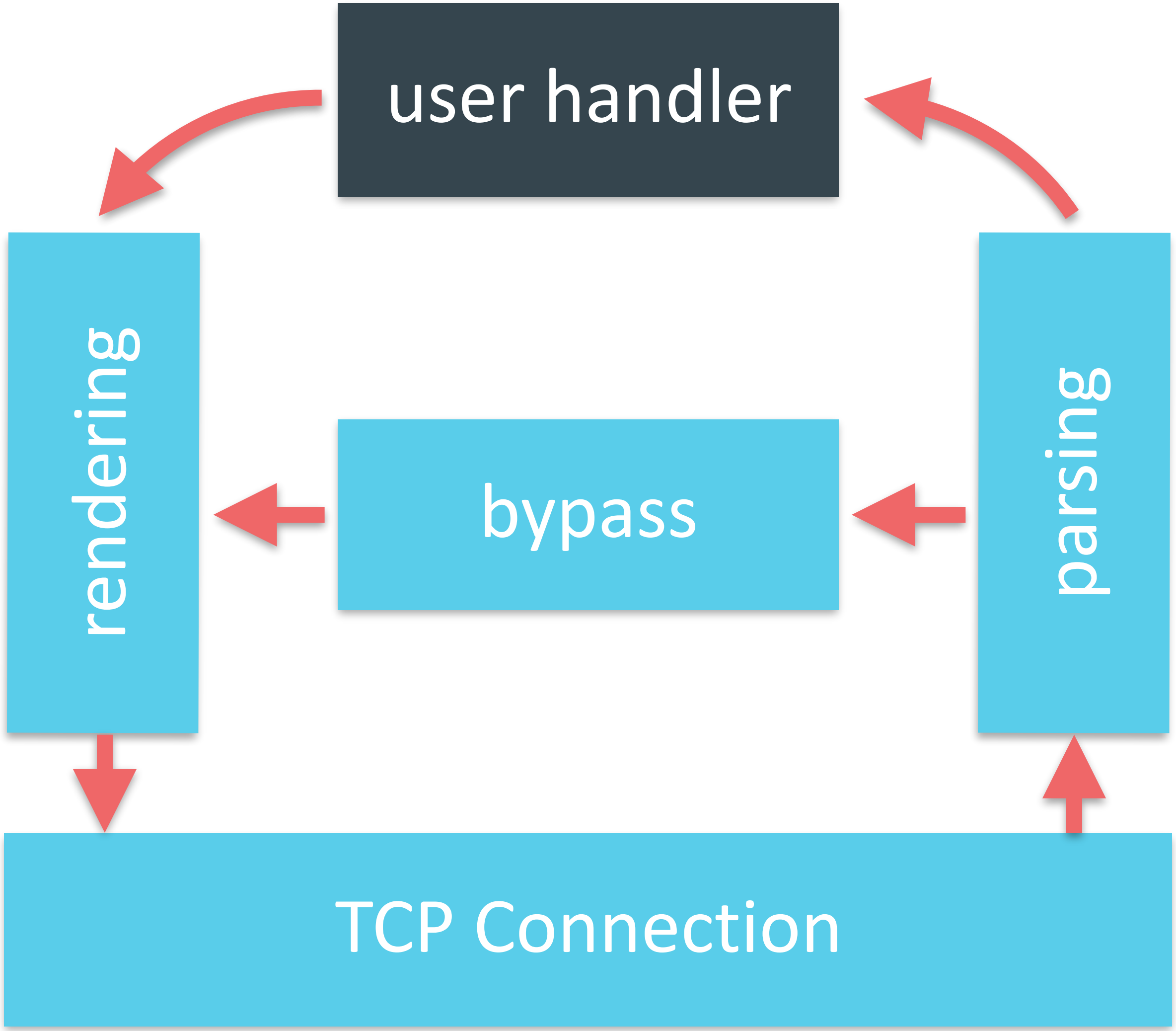
Canonical papers

- Carl Hewitt; Peter Bishop; Richard Steiger (1973). A Universal Modular Actor Formalism for Artificial Intelligence. IJCAI.
- Gul Agha (1986). Actors: A Model of Concurrent Computation in Distributed Systems. Doctoral Dissertation. MIT Press.

Akka Streams

- powered by Akka Actors because
  - execution
  - distribution
  - resilience
- Typesafe (pun intended) streaming through Actors with bounded buffering
- Flow & Duct DSL is a lifted representation
  - Uses pluggable materialisation

Akka HTTP Server Overview



Akka HTTP Server Part 1

```
val requestProducer =
 Flow(tcpConn.inputStream)
  .transform(rootParser)
  .splitWhen(_.isInstanceOf[MessageStart])
  .headAndTail // Flow[(Start, Producer[…])]
  .tee(bypassConsumer)
  .collect {
    case (x: RequestStart, entityParts) =>
      HttpServerPipeline.constructRequest(x,
        entityParts) }
  .toProducer(materializer)
```

Akka HTTP Server Part 2

```
val (bypassConsumer, bypassProducer) =
 Duct[(RequestOutput, Producer[RequestOutput])]
  .collect[MessageStart with RequestOutput]
    { case (x: MessageStart, _) => x }
  .build(materializer)
```

Akka HTTP Server Part 3

```scala
val responseConsumer =
 Duct[HttpResponse]
   .merge(bypassProducer)
   .transform(applyApplicationBypass)
   .transform(rendererFactory.newRenderer)
   .flatten(concat)
   .transform(logErrors)
   .toProducer(materializer)
   .produceTo(tcpConn.outputStream)
```

Akka HTTP server Part 4

```scala
val logErrors =
  new Transformer[ByteString, ByteString] {
    def onNext(element: ByteString) =
      element :: Nil
    override def onError(cause: Throwable) =
      log.error(cause, "Response stream error")
  }
```

Advanced Live Demo

What’s next for Akka Streams?

Opportunity: API

- Current API is minimal
  - Establish core functionality and take it from there
- Naming: Use established terminology or simplified?
- Both Scala and Java APIs
  - Allows for use by other JVM-hosted languages

Opportunity: Self-tuning back pressure

- Each processing stage can know
  - Latency between requesting more and getting more
  - Latency for internal processing
  - Behavior of downstream demand
    - Latency between satisfying and receiving more
    - Trends in requested demand (patterns)
      - Lock-step
      - N-buffered
      - N + X-buffered
      - “chaotic”

Opportunity: Operation Fusion

- Compile-time, using Scala Macros
  - filter ++ map == collect
  - map ++ filter == collect?
- Run-time, using intra-stage simplification
  - Rule: <any> ++ identity == <any>
    Rule: identity ++ <any> == <any>
  - filter ++ dropUntil(cond) ++ map
  - filter ++ identity ++ map == collect

Opportunity: Operation Elision

- Compile-time, using Scala Macros
  - fold ++ take(n where n > 0) == fold
  - drop(0) == identity
  - <any> concat identity == <any>
- Run-time, using intra-stage simplification
  - map ++ dropUntil(cond) ++ take(N)
  - map ++ identity ++ take(N)
  - map ++ take(N)

Opportunity: Execution optimizations

- synchronous intra-stage execution N steps then trampoline and/or give control to other Thread / Flow
- We already do inter-stage execution reduction

Opportunity: Distributed Streams

- Encode Reactive Streams as a transport protocol
    - Possibility to run over
        - TCP
        - UDP
        - … essentially any bidirectional channel
    - MUX-ing streams
- Materialize a Flow on a cluster of Akka nodes

Outro: How do I get my hands on this?

- http://reactive-streams.org/
- https://github.com/reactive-streams
- Early Preview is available:

```
"org.reactivestreams" % "reactive-streams-spi" % "0.3"
"com.typesafe.akka" %% "akka-stream-experimental" % "0.3"
```

- check out the Activator template "Akka Streams with Scala!" (https://github.com/typesafehub/activator-akka-stream-scala)

Typesafe