Akka Streams

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Conventions in the slides

The following typographical conventions are used in this material:

Italic
Indicates new terms, URLs, email addresses, filenames, and file extensions.

`Constant width`
Used for program listings, as well as within paragraphs to refer to program elements such as variable or function names, databases, data types, environment variables, statements, and keywords.

`Constant width bold` Shows commands or other text that should be typed literally by the user.

`Constant width italic`
Shows text that should be replaced with user-supplied values or by values determined by context.

Shell Conventions

All shells (bash, zsh, Windows Shell) are represented as `%`

```
% calendar
```

All SBT shells are represented as `>`

```
> compile
```

All Scala REPL and SBT Consoles are represented as `scala>`

```
scala>
```

About Akka Streams

Akka Streams

- Backed by Actors
- Stream processors much like their competitors RxJava, Project Reactor
- Asynchronous Process of Streams can be difficult

Understanding Java Futures

`Future` Defined

> Future definition - `Future` represents the lifecycle of a task and provides methods to test whether the task has completed or has been canceled. `Future` can only move forwards and once complete it stays in that state forever.
>
> — Java Concurrency in Practice, Brian Goetz

Thread Pools

Before setting up a future, a thread pool is required to perform an asynchronous computation. Each pool with return an `ExecutorService`.

There are a few thread pools to choose from:

- `FixedThreadPool`
- `CachedThreadPool`
- `SingleThreadExecutor`
- `ScheduledThreadPool`
- `ForkJoinThreadPool`

Fixed Thread Pool

- "Creates a thread pool that reuses a fixed number of threads operating off a shared unbounded queue."
- Keeps threads constant and uses the queue to manage tasks waiting to be run
- If a thread fails, a new one is created in its stead
- If all threads are taken up, it will wait on an unbounded queue for the next available thread

Cached Thread Pool

- Flexible thread pool implementation that will reuse previously constructed threads if they are available
- If no existing thread is available, a new thread is created and added to the pool
- Threads that have not been used for sixty seconds are terminated and removed from the cache

Single Thread Executor

- Creates an Executor that uses a single worker thread operating off an unbounded queue
- If a thread terminates due to a failure during execution prior to shutdown, a new one will take its place if needed to execute subsequent tasks.

Scheduled Thread Pool

- Can run your tasks after a delay or periodically
- This method does not return an `ExecutorService`, but a `ScheduledExecutorService`
- Runs periodically until `canceled()` is called.

Fork Join Thread Pool

- An `ExecutorService`, that participates in *work-stealing*
- By default when a task creates other tasks (`ForkJoinTasks`) they are placed on the same on queue as the main task.
- *Work-stealing* is when a processor runs out of work, it looks at the queues of other processors and "steals" their work items.
- Not a member of Executors. Created by instantiation
- Brought up since this will be in many cases the "default" thread pool on the JVM

Basic Future Blocking (JDK 5)

```
ExecutorService fixedThreadPool = Executors.newFixedThreadPool(5);

Callable<Integer> callable = new Callable<Integer>() {
    @Override
    public Integer call() throws Exception {
        System.out.println("Inside the future: " +
                Thread.currentThread().getName());
        Thread.sleep(5000);
        return 5 + 3;
    }
};

System.out.println("In test:" + Thread.currentThread().getName());
Future<Integer> future = fixedThreadPool.submit(callable);

//This will block
Integer result = future.get(); //block
System.out.println("result = " + result);
```

Basic Future Asynchronous (JDK 5)

```
ExecutorService cachedThreadPool = Executors.newCachedThreadPool();

Callable<Integer> callable = new Callable<Integer>() {
    @Override
    public Integer call() throws Exception {
        Thread.sleep(3000);
        return 5 + 3;
    }
};

Future<Integer> future = cachedThreadPool.submit(callable);

//This is proper asynchrony, but rather ugly
while (!future.isDone()) {
    System.out.println(
       "I am doing something else on thread: " +
       Thread.currentThread().getName());
}

Integer result = future.get();
```

Applicable to Java 8

Java’s `CompletionStage`

`CompletionStage`

- A stage of asynchronous computation
- Performs an action or computes a value when the previous stage completes
- An API that cleanly handles asynchronous processing of chained `Future`
- Every stage can be performed as a:
  - `Function`
  - `Consumer`
  - `Runnable`
- Uses an `ExecutorService` to drive each stage
- Is also a basic component of Akka Streams

`CompletableStage` initialization with `supplyAsync`

- `supplyAsync` provides the data contained in the `Supplier`
- Processing takes place on a different `Thread`
- Requires an `ExecutorService` for thread pools

```
ExecutorService executorService = Executors.newCachedThreadPool();

integerFuture1 = CompletableFuture
  .supplyAsync(() -> {
      try {
          System.out.println(
              "intFuture1 is Sleeping in thread: "
              + Thread.currentThread().getName());
          Thread.sleep(3000);
      } catch (InterruptedException e) {
          e.printStackTrace();
      }
      return 5;
  }, executorService);
```

Simple Chain using `CompletableStage`

- Each `CompletableStage` can be interlinked
- This is the simplest flow of data, from source to sink

```
integerFuture1.thenAccept(System.out::println); //5
```

Functional Map analogy with `thenApply`

- `thenApply` is analogous to a functional `map`
- `map` applies a function to every container providing a copy of the container with the modified contents

```
CompletableFuture<String> future =
   integerFuture1.thenApply(x -> {
       System.out.println("In Block:" +
               Thread.currentThread().getName());
       return String.valueOf(x + 19);
   });
future.thenAccept(s -> {
    System.out.println(
       "In the accept: " +
       Thread.currentThread().getName());
    System.out.println(s);
});
```

Inlining `thenApply`

- In the previous example, processing was done separate
- All functions can be inlined to express a chain of processing

```
integerFuture1
   .thenApply(x -> String.valueOf(x + 19))
   .thenAccept(System.out::println);
```

Lab: Running `CompletableFuture` examples

Step 1: In the akka-streams-study project, under the *src/main/java* folder, open `com.xyzcorp.CompletableFutureTest`.

Step 2: Use your IDE's faculties to run the tests individually to see how `CompletableFuture` and `CompletableStage` works

	Running Tests in IntelliJ	Running Tests in Eclipse
Windows/Linux	`CTRL + SHIFT + F10` or `SHIFT + F10`	`ALT + SHIFT + X, T`

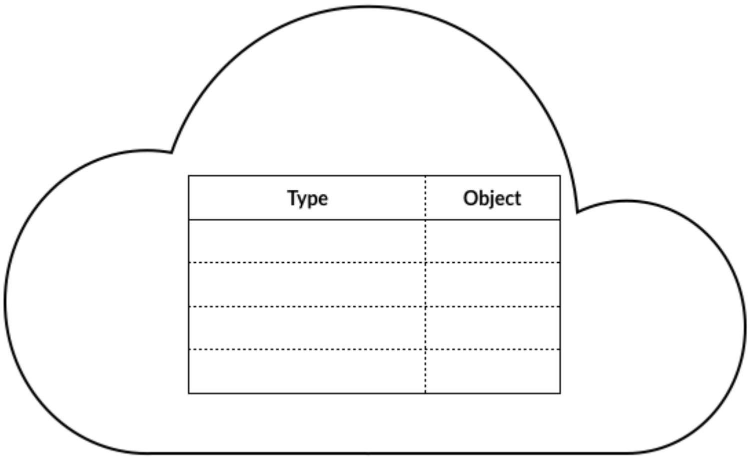
	Running Tests in IntelliJ	Running Tests in Eclipse
Mac	`CTRL + R` or `CTRL + SHIFT + F10`	`CMD + OPTION + X, T`

For Eclipse Run the Test in the method header, for IntelliJ, run the Test anywhere within the method

implicit

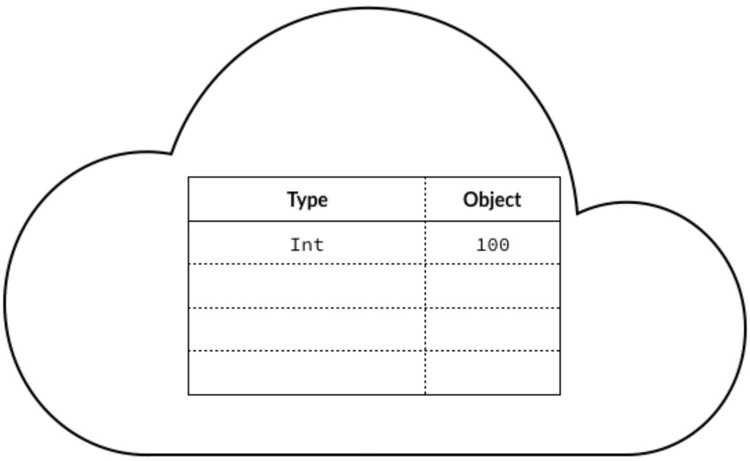
implicit

- `implicit` is like an invisible `Map[Class[A], A]` where `A` is any object and it is tied into the scope
- Whatever type is required the object that it corresponds to that type will be injected automatically.



implicit

- `implicit` in this case bounds an `Int` of `100`
- Once established we can call upon the `implicit` binding to a binding parameter group



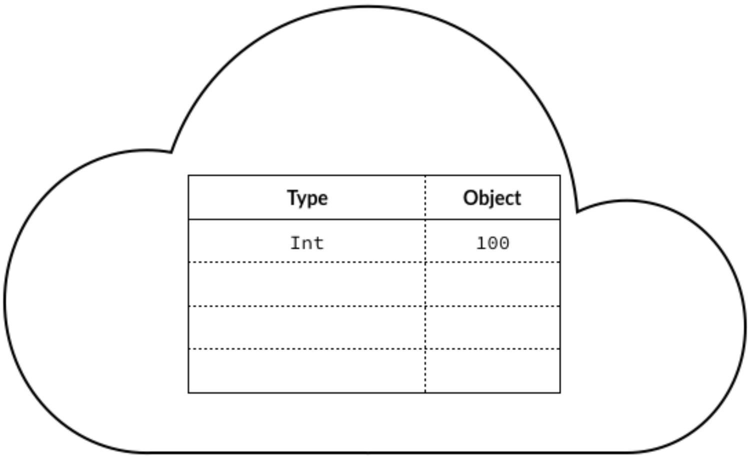

```
implicit val hourlyRate = 100

def calcPayment(hours: Int)(implicit rate: Int) = hours * rate

calcPayment(50) should be(5000)
```

Overriding an `implicit` manually

- You can always override the any `implicit` manually



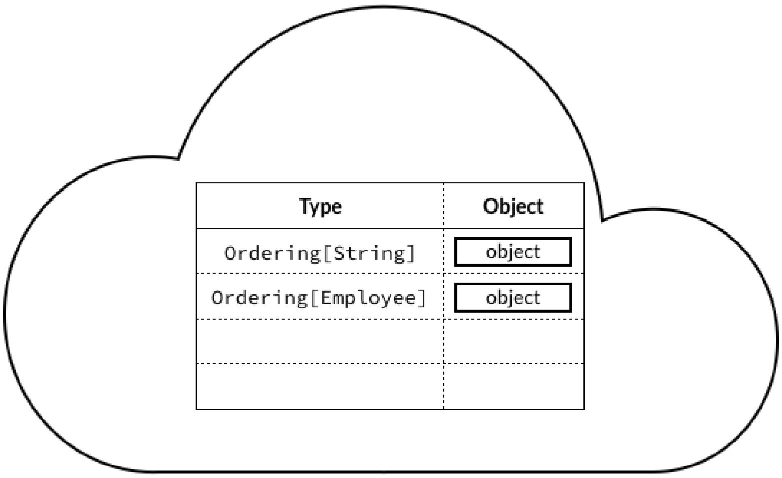

```scala
implicit val hourlyRate = 100

def calcPayment(hours: Int)(implicit rate: Int) = hours * rate

calcPayment(50)(200) should be(10000)
```

Setting up an `implicit` for `Ordering[T]`

- You can establish an `implicit` for ordering inside of a collection or any construct with `Ordering[T]`
- This is also known as a *Type Class*

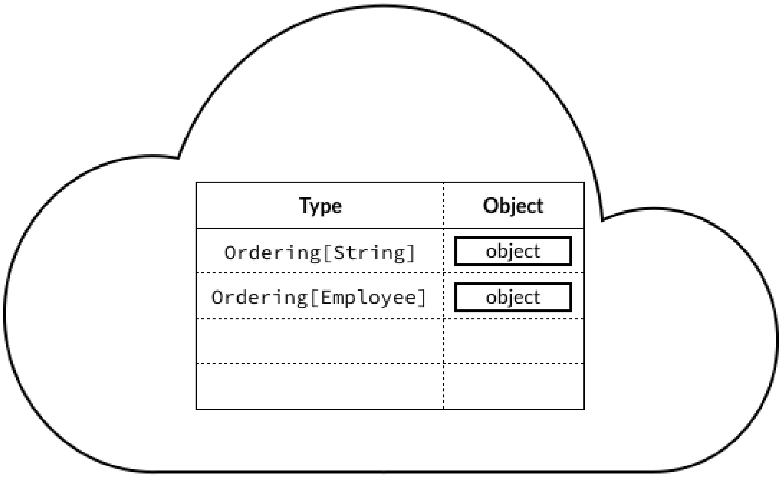


```scala
case class Employee(firstName:String, lastName:String)

implicit val employeeOrderingByLastName: Ordering[Employee] =
  new Ordering[Employee] {
    override def compare(x: Employee, y: Employee): Int = {
      x.lastName.compareToIgnoreCase(y.lastName)
    }
  }
```

Applying the `implicit` for `Ordering[T]`

Once this `implicit` is established there is an `implicit` bound on how to order an `Employee`




```scala
List(new Employee("Eric", "Clapton"),
        new Employee("Jeff", "Beck"),
        new Employee("Ringo", "Starr"),
        new Employee("Paul", "McCartney"),
        new Employee("John", "Lennon"),
        new Employee("George", "Harrison")).sorted
```

Which yields the result:

```scala
List(new Employee("Jeff", "Beck"),
        new Employee("Eric", "Clapton"),
        new Employee("George", "Harrison"),
        new Employee("John", "Lennon"),
        new Employee("Paul", "McCartney"),
        new Employee("Ringo", "Starr"))
```

In order to avoid any conflicts, it is up to you, the programmer, to decide in what scope `implicit` are applied

Why did `implicit Ordering[Employee]` work?

- Here is the Scala API signature for `sorted`
- Notice the `implicit` definition in the method signature
- It requires that an implicit bound be available in order to process

```
def sorted[B >: A](implicit ord: math.Ordering[B]): List[A]
```

Sorts this sequence according to an Ordering.

The sort is stable. That is, elements that are equal (as determined by lt) appear in the same order in the sorted sequence as in the original.

ord	the ordering to be used to compare elements.
returns	a sequence consisting of the elements of this sequence sorted according to the ordering ord.

Definition Classes	SeqLike
See also	scala.math.Ordering

Establishing an Execution Context

`ExecutionContext`

- A `scala.util.concurrent.ExecutionContext`
  - Is a wrapper around and `Executor` that is used to `implicitly` bind a thread pool.
  - Is a `trait`
  - Can be adapted from to wrap a premade `java.util.concurrent.Executor`

`scala.util.concurrent.ExecutionContext.global`

- `ExecutionContext` backed by a `ForkJoinPool`
- Automatically set to the number of available processors
- Can potentially add more if any of the threads are blocked
- This can be overridden by applying any of the following VM attributes:
  - `scala.concurrent.context.minThreads`
  - `scala.concurrent.context.numThreads`
  - `scala.concurrent.context.maxThreads`

Retreiving the `ExecutionContext` global

- We can establish an `ExecutionContext` with an `implicit`
- This will make available the `ExecutionContext` whenever required

```
implicit val ec = ExecutionContext.global
```

- This can also be done as an `import`
- It also establishes an `ExecutionContext` implicitly

```
import ExecutionContext.Implicits.global
```

Converting a Java `Executor` to an `ExecutionContext`

- If there a specialized thread pool that you would like use as an `ExecutionContext`, use `fromExecutor`

```
val executor = ExecutionContext
                 .fromExecutor
                   (Executors.newCachedThreadPool())
```

Scala Futures

Semantic Differences with Scala `Future`

- A Scala `Future` is either *completed* or *not completed*
- When a `Future` is completed with a *value* it is *successfully completed*
- When a `Future` throws a `java.util.Throwable` then it has *failed*

Creating a `Future`

- `scala.concurrent.Future[T]` is created with an `apply` in its `object`
- Requires an `ExecutionContext` to be available either explicitly or implicitly
  - `import scala.concurrent.ExecutionContext.Implicits.global`
  - `implicit val executionContext = scala.concurrent.ExecutionContext.global`
  - `implicit val executionContext = scala.concurrent.ExecutionContext.fromExecutor(…)`

Using `foreach` to receive `Future` results

- To receive a the contents of a `Future` you can use `foreach`

```
val future:Future[Int] = ...
future.foreach(x => println(x))
```

Using `onComplete` to receive `Future` results

- `onComplete`
  - Will accept a `Function` that is given a `Try` input
  - The signature is the following:

```
onComplete[U](f: (Try[T]) => U)(implicit executor: ExecutionContext):
Unit
```

`Try`

- `Try[T]` is an `abstract class` that has two `sealed` children
  - `Success[T]` - Represents a success, contains the answer of type `T`
  - `Failure[T]` - Represents a failure, contains the `Throwable` that caused the failure

`sealed` means an abstraction like `abstract` and `trait` where all the children are declared and no one else can subclass the `sealed` abstraction

Lab: Creating a Future

Step 1: In the akka-streams-study project, and in the *src/test/scala* folder, and in the package `com.xyzcorp.futures` open the `FuturesSpec`

Step 2: Run the first test in your IDE or on in SBT using

```
> testOnly com.xyzcorp.futures.FuturesSpec -- -z "Case 1"
```

Step 3: Refactor the `ExecutionContext` so that you do not require to inject it into the `Future` declaration or the `foreach`

Lab: Processing a `Future` with `onComplete`

Step 1: Continuing inside `com.xyzcorp.futures.FuturesSpec`, we will have an instructor led exercise and type inside the `"A basic future. Processing it using onComplete"` test

Step 2: We will create a future similar to the following:

```scala
val eventualString: Future[String] = Future {
  val num = scala.util.Random.nextInt(2)
  if (num == 1) "Awesome!"
  else throw new RuntimeException(s"Invalid number $num")
}
```

Step 3: Then we will get the response of the `Future` by using `onComplete`

Step 4: We will then run the test in your IDE or on in SBT using

```
> testOnly com.xyzcorp.futures.FuturesSpec -- -z "Case 2"
```

Akka

About Akka

- Set of libraries used to create concurrent, fault-tolerant and scalable applications.
- It contains many API packages:
- Actors, Logging, Futures, STM, Dispatchers, Finite State Machines, and more…
- We are going to only focus on some of the core items.
- Akka’s managing processes can run on
    - in the Same VM
    - in a Remote VM
- Akka’s Actor’s are a replacement Scala’s Actors that came in earlier versions

Starting with Actors

- Based on the Actor Model from Erlang.
- Encapsulates State and Behavior
- Concurrent processors that exchange messages.
- Each message is immutable (cannot be changed, this is required!)
- Each message should not be a closure
- Breath of fresh air if you have suffered concurrency

Akka Rules

- The messages to and from actors cannot be
    - Mutable
    - Closure

Immutable Scala Classes

```
case class Person(firstName:string, lastName:string)
```

or

```
class Person(val firstName:String, val lastName:String) {
  override def toString() = {...}
  override def equals(x:AnyRef):Boolean = {...}
  override def hashCode:Int = {...}
}
```

Recognizing Closures

```
var x = 3
val y = (z:Int) => x + z
def foo(w: Int => Int) = w(5)
println(foo(y)); //8
```

Location Transparency

- Vertical and Horizontal Growth
- Horizontal Growth driven by Remoting systems
- Vertical Growth driven by routers
- All configuration based

More about `actorOf()`

- Creates an actor onto a `ActorSystem`
- Creates an actor given the a set of properties to describe the Actor
- Creates an Actor with an identifiable name, if provided
- Returns an `ActorRef`
- If actorOf is called *inside* of another actor, that new actor becomes a child of that actor

`actorSelection()`

- Was ActorFor which is now deprecated
- Actor references can be looked up using `actorSystem.actorSelection(…)` method.
- `actorSystem.actorSelection` returns a `ActorSelection` object that abstracts over local or remote reference.
- `ActorSelection` can be used as long as the actor is alive.
- Only ever looks up an existing actor, i.e. does not create one.
- The actor must exist or you will receive an EmptyLocalActorRef
- For Remote Actor References, a search by path on the remote system will occur.

About ActorRefs

- Any subtype of ActorRef
- ActorRef is the only way to interact with an Actor
- Intent is to send messages to Actor that it represents, proxy.
- Each actor has reference to `self()` refers to it's own reference.
- Each actor also has reference to the `sender()`, the actor that sent the message.
- Any reference can be sent to another actor so that actor can send messages to it.

Lab: Reviewing Akka-Actors

Step 1: In the akka-streams-study, in the *src/test/scala* folder and in the `com.xyzcorp.akka` package open the `SimpleActorSpec`

Step 2: Run the tests individually in your IDE, below is a table of keymaps to run the test

	Running Tests in IntelliJ	Running Tests in Eclipse
Windows/Linux	`CTRL + SHIFT + F10` or `SHIFT + F10`	`ALT + SHIFT + X, T`
Mac	`CTRL + R` or `CTRL + SHIFT + F10`	`CMD + OPTION + X, T`

Step 3: Run the tests inside of SBT shell using the command

```
> testOnly com.xyzcorp.akka.SimpleActorTest -- -z "Case 1"
```

`"Case 1"` is a substring of the test name. That way you can run individual tests

Reactive Streams

reactivestreams.org

- http://reactivestreams.org
- Standard for asynchronous stream processing with non-blocking back pressure
- Goals is to govern the exchange of stream data across an asynchronous boundary without buffering needless arbitrary data
- Find a minimal set of interfaces, methods and protocols that will describe the necessary operations and entities to achieve the goal
- Not necessary for synchronous process only asynchronous processing

Reactive Streams API

- API has been standardized as of April 30, 2015
- 1.0.0 version of Reactive Streams API
- Contains:
    - Java API
    - Specification
    - TCK (Technology Compatibility Kit)
    - Implementation Examples

What Asynchronous Streams?

- Increased need for transferring large quantities of data across asynchronous boundaries
    - CPU Boundaries
    - Networking Systems

Backpressure

- The producer may not always be the same speed as the consumer
- The consumer will often require that it hold up the source processing
- This primarily occurs when the consumer is slower than the producer
- If no backpressure is defined then data processing will grind to a halt

Understanding the Reactive Streams API

- A collection of four main `interface`

- `Subscriber`
- `Publisher`
- `Subscription`
- `Processor`

`Publisher`

- Simply publishes the data
- Provider of a potentially unbounded number of sequenced elements

```
public interface Publisher<T> {
    public void subscribe(Subscriber<? super T> s);
}
```

- Publishing them according to the demand received from its `Subscriber`(s)

`Subscriber`

- Will `receive` call to `onSubscribe(Subscription)` after a `Subscriber` is given to the `Publisher`
- Also contains calls sent from the source when:
  - A new element is sent `onNext`
  - When an error occurs `onError`
  - When the stream is possibly done `onComplete`

```
public interface Subscriber<T> {
    public void onSubscribe(Subscription s);
    public void onNext(T t);
    public void onError(Throwable t);
    public void onComplete();
}
```

`Subscription`

- The `Subscription` represents the `Subscription` itself sent to the `Subscriber`
- Through the `Subscription` a `Subscriber`:
  - Can request more information from its `Source` using `request`
  - Can cancel the flow by calling `cancel`

```java
public interface Subscription {
    public void request(long n);
    public void cancel();
}
```

Processor

- A Combination of both a `Subscriber` and `Publisher`
- Meant to be snapped in to a processing flow between the `Source` and `Sink` and transform the data
- It is the "go-between" linking components in a stream

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

Akka Streams

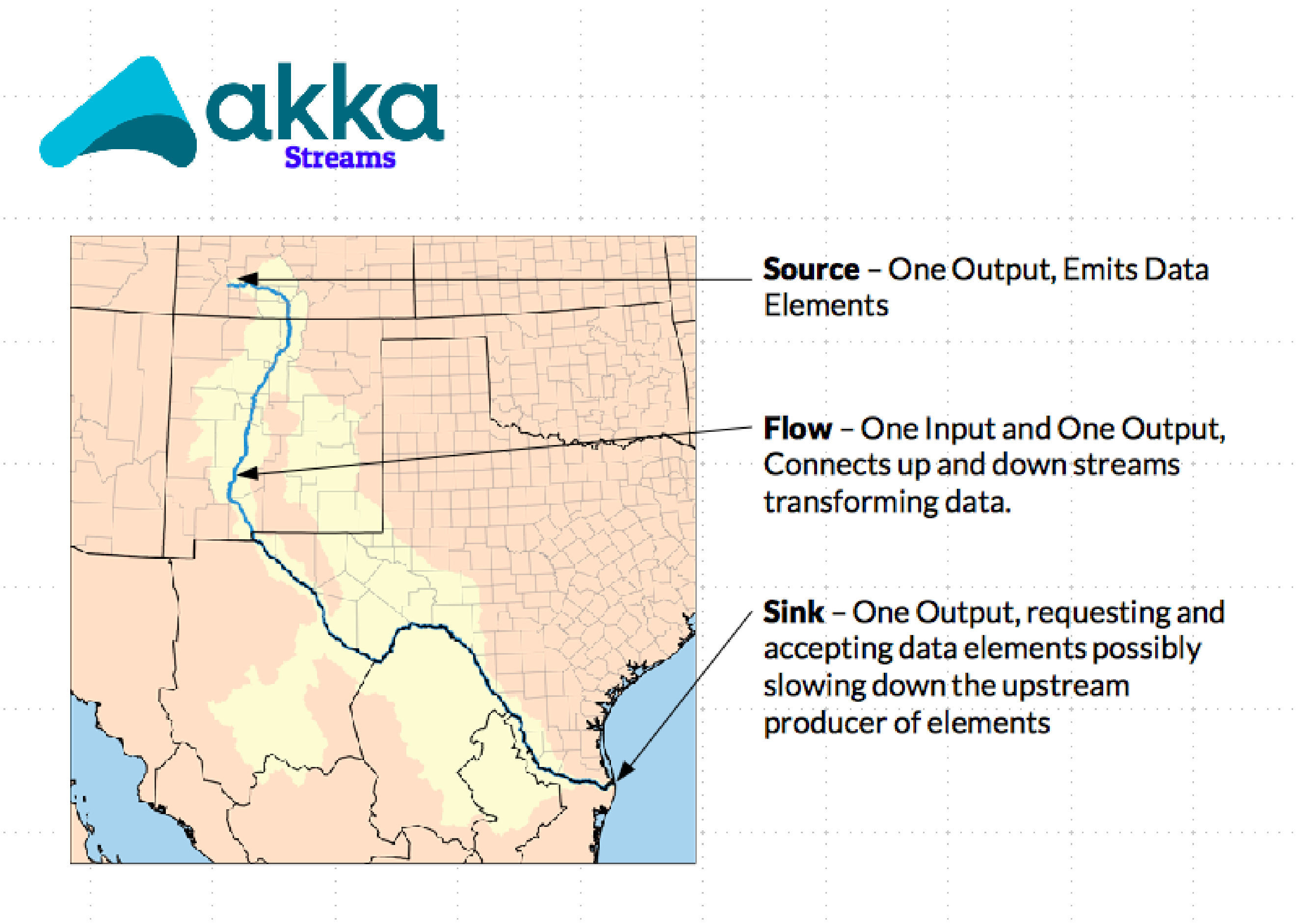
Akka Streams Overview

- Builds on the idea of flows and flow graphs that define how a stream is processed
- Streams are built with reusable pieces either:
  - Prepackaged components
  - Custom made composites

Relationship between Akka Streams and the Reactive Streams API

- The scope of Reactive Streams is defining a mechanism to move data across an asynchronous boundary
- Akka Streams Implementation Uses Reactive Streams Internally
- Akka Streams API is meant not to expose the Reactive Streams API

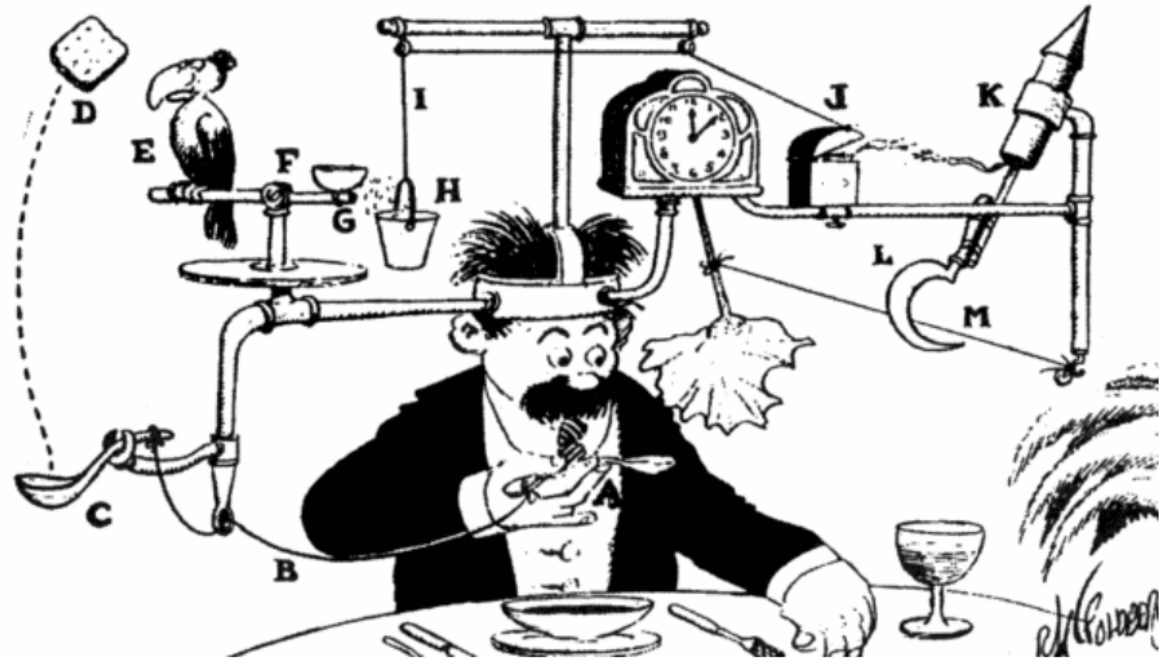
Akka Streams River Analogy



Akka Streams Pipe Analogy

Akka Streams Lightening Analogy

Akka Streams Rube Goldberg Analogy

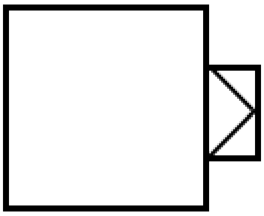


Think Rube Goldberg machines!

Source

Defining Source

- A Source that accepts a single item
- In the following example the first element `[Int]` is the type of element that this source emits



- The second one is some auxiliary value that certain components may add.
- When no auxiliary value is produced `akka.NotUsed` is used in its place.
- The following is an example of a `Source` that emits one element

```
val single: Source[Int, NotUsed] = Source.single(3)
```

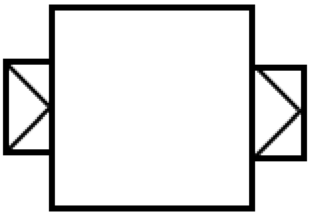
Other Source

- With each update of Akka Streams another manifestation of `Source` is developed
- You can create many of these `Source`
    - `cycle`
    - `fromFuture`
    - `fromPublisher` (from the Reactive Streams Library)
    - `lazily`
    - more…

Flow

Defining Flow

- Flow are the interlinking pieces that are the intermediate computations
- A processing stage which has exactly one input and output
- Connects its upstream and downstream components by transforming the data elements flowing through it
- Are immutable, thread-safe, and freely shareable



Why Flow?

- A Source can be manipulated by anyone of the methods, for example it contains map, but it is still a Source

```
val result:Source[Int, NotUsed] =
   Source(1 to 100).map(x => x + 10)
```

- A Flow gives us the opportunity to create a separate component that represent the action like map

```
val mapIntFlow:Flow[Int, NotUsed] =
   Flow.apply[Int]().map(x => x + 10)
```

- The above can be refactored simply to:

```
val mapIntFlow = Flow[Int].map(_ + 10)
```

Connecting the Flow

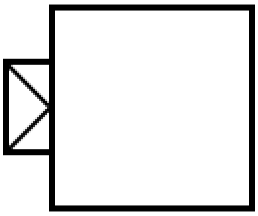
- Once a Flow is created, it can then be connected to a Source with via

```
val mapIntFlow = Flow[Int].map(_ + 10)
val newSource = Source(1 to 10).via(mapIntFlow)
```

`Sink`

Defining `Sink`

- `Sink` is the where all data is finally accumulated
- A processing stage with exactly one input
- Requesting and accepting data elements possibly slowing down the upstream producer of elements



Why `Sink`?

- A `Sink` gives us the opportunity to create a separate component that represents the final stage for stream processing

```
val foldSink = Sink.fold[Int, Int](0)(_ + _)
val printlnSink = Sink.foreach[Int](println)
```

- The sink can then be applied to as a final stage using `to`
- This will create what is called a `RunnableGraph`, which can now be `run`

```
val mapIntFlow: Flow[Int, Int, NotUsed] =
   Flow[Int].map(x => 10 + x)

val printlnSink = Sink.foreach[Int](println)

val graph: RunnableGraph[NotUsed] =
   Source(1 to 10).via(mapIntFlow).to(printlnSink)
```

`RunnableGraph`

Defining `RunnableGraph`

- Once `Source`, all `Flow` and `Sink` are connected it is a `RunnableGraph`
- Defined as a Flow that has both ends "attached" to a `Source` and `Sink` respectively
- Is ready to be `run()`

```
val graph: RunnableGraph[NotUsed] =
   Source(1 to 10)
      .via(mapIntFlow)
      .to(printlnSink)
```

Running the `RunnableGraph`

- Once contained as a `RunnableGraph`, you need the following to run
  - An `ActorSystem`
  - An `ExecutionContext`
  - A `Materializer`
- A `Materializer` is a an engine, backed by `Actor`, that will process the stream

A `RunnableGraph` by example

Step 1: Establish all the required elements, `actorSystem`, `materializer`, and `executionContext`

```
implicit val system: ActorSystem =
   ActorSystem("MyActorSystem")
implicit val materializer: ActorMaterializer =
   ActorMaterializer()
implicit val executionContext: ExecutionContextExecutor =
   system.dispatcher
```

`system.dispatcher` merely obtains the thread pool from the `ActorSystem`

Step 2: Create a `RunnableGraph`, and run it

```
val mapIntFlow: Flow[Int, Int, NotUsed] =
   Flow[Int].map(x => 10 + x)
val printlnSink =
   Sink.foreach[Int](println)
val graph: RunnableGraph[NotUsed] =
   Source(1 to 10)
      .via(mapIntFlow)
      .to(printlnSink)
graph.run()
```

Lab: Creating a `RunnableGraph`

Step 1: In the akka-streams-study project, and in the *src/test/java* folder and in the `com.xyzcorp.akka.streams` package, and in the *SimpleStreamSpec.scala*, locate the "Case 4: A stream can be created by independent components"

Step 2: Create the example that we have been discussing, inside of the "A stream can be created by independent components" test. Here it is again, but with an explicit `materializer`.

```
val mapIntFlow: Flow[Int, Int, NotUsed] =
   Flow[Int].map(x => 10 + x)
val printlnSink =
   Sink.foreach[Int](println)
val graph: RunnableGraph[NotUsed] =
   Source(1 to 10)
      .via(mapIntFlow)
      .to(printlnSink)
graph.run()(materializer)
Thread.sleep(1000)
```

Step 3: Run the `RunnableGraph` created

Step 4: Refactor as much cruft as you can away to make it as inline as possible

Composite Stages

Composite `Source`

- A `Source` can be composited with any of its methods, and still be a `Source`

```
val composite:Source[Int, NotUsed] =
   Source(1 to 10)
     .map(x => x + 10)
```

- A `Source` can be composited also with `via`, which applies a `Flow`, and still be a `Source`

```
val mapIntFlow: Flow[Int, Int, NotUsed] =
   Flow[Int].map(x => 10 + x)
val composite:Source[Int, NotUsed] =
   Source(1 to 10)
      .via(mapIntFlow)
```

Composite `Sink`

- A `Sink` can be composited with any of its methods, and still be a `Sink`

```
val composite:Source[Int, NotUsed] =
   Flow[Int]
      .map(x => x + 10)
      .to(String.foreach(println))
```

- A `Sink` can be composited also with `to`, which applies a `Flow`, and can still be a `Sink`

```
val mapIntFlow:Flow[Int, Int, NotUsed] =
   Flow[Int]
      .map(x => 10 + x)
val compositeSink:Sink[Int, NotUsed] =
   mapIntFlow
      .to(Sink.foreach(println))
```

`viaMat` and `toMat`

Recalling the auxiliary value

- In streams there is an auxialliary value per stream
- This can be used to:
  - to manipulate the stream
  - to provide added information
- It is your choice which you want to use by either pull:
  - The left with `Keep.left`
  - The right with `Keep.right`

Which one? `viaMat` or `toMat`?

- As a mental note:
  - `via` is used for `Flow`
  - `to` is used for `Sink`
- Therefore:
  - `viaMat`, select element as a `Flow`
  - `toMat`, select element as a `Sink`

Lab: `toMat`

Step 1: In the akka-streams-study project, and in the *src/test/scala* folder and in the *com.xyzcorp.akka.streams* package, and in the *SimpleStreamSpec.scala*, locate the "Case 19: Perform a test with an async boundary which will run on a separate actor and dispatcher" test

Step 2: Run the method, in SBT using the following which will only run the single test

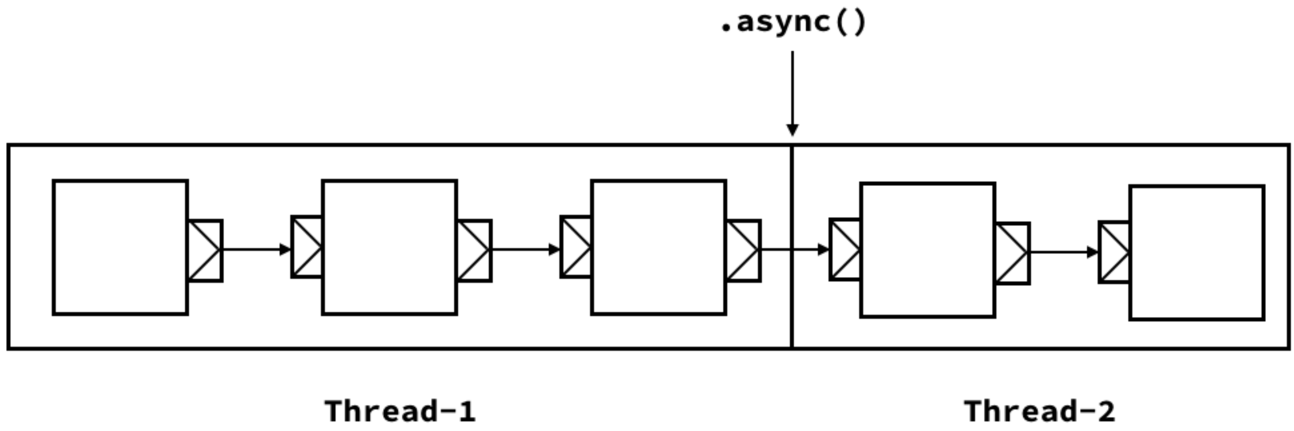
```
> testOnly com.xyzcorp.akka.streams.SimpleStreamSpec -- -z "Case 19"
```

Step 3: Disassemble and discover types to understand how all of it fits together. Introduce explicit types to see how it all fits together and try different combinations

async

Using async

- `async` is a "combinator" that places a thread before the next component in the Stream
- Included in the boundary is a process that runs within the different `Thread`



async by Example

```
import scala.language.postfixOps
Source(1 to 10)
  .map(1 +)
  .map(x => {
    println("Top: " + currentThreadName)
    x
  })
  .async //We are setting an async boundary
  .map(x => {
    println("Bottom " + currentThreadName)
    x
  })
  .filter(x => x % 2 == 0)
  .runForeach(println)
```

Lab: async

Step 1: In the akka-streams-study project, and in the *src/test/scala* folder and in the *com.xyzcorp.akka.streams* package, locate the "Perform a test with an async boundary which will run on a separate actor and dispatcher" test in the *SimpleStreamSpec.scala*

Step 2: Run the method, in SBT using the following which will only run the single test

```
> testOnly com.xyzcorp.akka.streams.SimpleStreamSpec -- -z "async
boundary"
```

Step 3: Disassemble and discover types to understand how all of it fits together. Introduce explicit types to see how it all fits together and try different combinations

Failure

Dealing with Failure

- Many times dealing with a failure can be very disruptive
- You can deal with failures as
  - `recover` to emit a final element then complete the stream normally on upstream failure
  - `recoverWithRetries` to create a new upstream and start consuming from that on failure
  - Restarting sections of the stream after a backoff
  - Using a supervision strategy for stages that support it

`recover`

- Recover will intercept a call, and stop with one element marking the end
- This will provide a non-disruptive exit from the stream

```
Source(10 to 0 by -1)
      .async
      .map(x => Some(100 / x))
      .recover { case t: Throwable => None }
      .runForeach(println)
```

`recoverWithRetries`

- This will provide a non-disruptive exit from the stream
- `recoverWithRetries` will:
  - Intercept a call
  - Retry the specified times
  - Stop with multiple elements marking the end

```
Source(10 to 0 by -1)
      .async
      .map(x => Some(100 / x))
      .recover { case t: Throwable => None }
      .runForeach(println)
```

Lab: Handling Failure

Step 1: In the akka-streams-study project, and in the *src/test/scala* folder and in the *com.xyzcorp.akka.streams* package, locate the "Perform a stream with a recover" and "Perform a stream with a recoverWithRetries" test

Step 2: Run the methods, in SBT, using the following which will only run the single test

```
> testOnly com.xyzcorp.akka.streams.SimpleStreamSpec -- -z "Case 20"
```

```
> testOnly com.xyzcorp.akka.streams.SimpleStreamSpec -- -z "Case 21"
```

Step 3: Disassemble and discover types to understand how all of it fits together. Introduce explicit types to see how it all fits together and try different combinations

Group Lab: Stock Prices

Group Lab: Stock Prices

Step 1: In the akka-streams-study project, and in the *src/test/scala* folder and in the `com.xyzcorp.akka.streams` package, create your own test at the end: "Process Stocks in a Stream"

Step 2: In the test, create a `Source[String, NotUsed]` that contains a list of your favorite stock symbols. Here are some to start with:

- ORCL
- MSFT
- T
- GOOG
- AAPL
- AMZN

Step 3: Given the following `Source`, use the following URL to retrieve the latest prices:

<a href="https://finance.google.com/finance/historical?output=csv&q=<symbol&gt" class="bare">https://finance.google.com/finance/historical?output=csv&q=<symbol&gt;

Step 4: Using Akka-Streams API Research, find various ways to manipulate the data. Also, try forking the stream to perform other operations.

Some Ideas:

- Find the average of the last 5 trade days
- Find the top volume trading days, and sort it

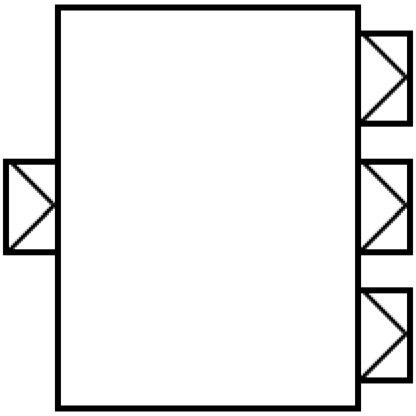
Graphs

Designing Graphs

- DSL designed graphs
- Reusable
- Used for complicated fan-in (merge) or fan-out (broadcast scenarios)

Fan Out

- `Broadcast[T]` - (1 input, N outputs) given an input element emits to each output
- `Balance[T]` - (1 input, N outputs) given an input element emits to one of its output ports
- `UnzipWith[In,A,B,...]` - (1 input, N outputs) takes a function of 1 input that given a value for each input emits N output elements (where N <= 20)
- `UnZip[A,B]` - (1 input, 2 outputs) splits a stream of `(A,B)` tuples into two streams, one of type A and one of type B



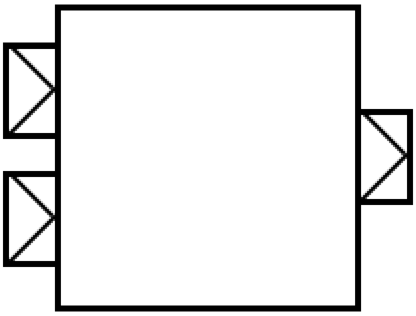
Source: https://doc.akka.io/docs/akka/2.5.4/scala/stream/stream-graphs.html

Fan In

- `Merge[In]` - (N inputs , 1 output) picks randomly from inputs pushing them one by one to its output
- `MergePreferred[In]` - like Merge but if elements are available on preferred port, it picks from it, otherwise randomly from others
- `MergePrioritized[In]` - like Merge but if elements are available on all input ports, it picks from them randomly based on their priority
- `ZipWith[A,B,...,Out]` - (N inputs, 1 output) which takes a function of `N` inputs that given a

value for each input emits 1 output element

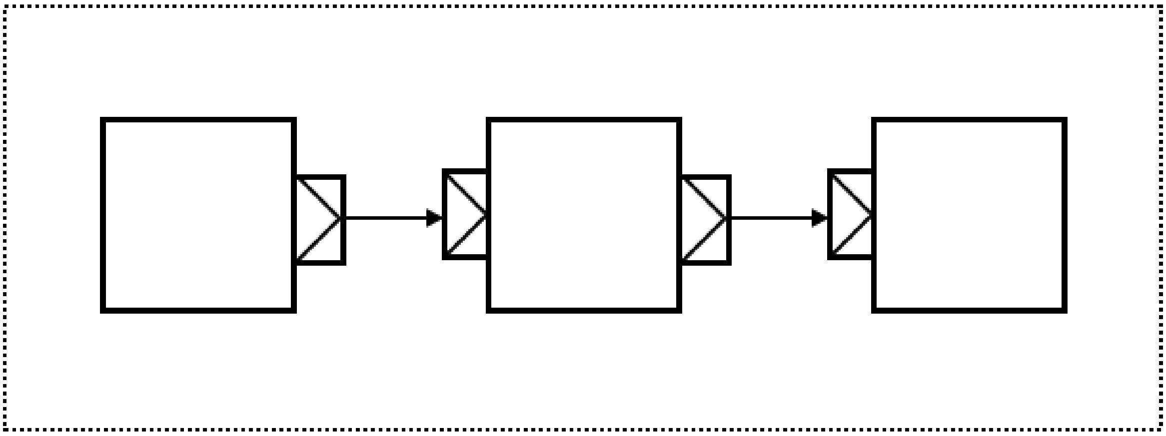
- `Zip[A,B]` - (2 inputs, 1 output) is a ZipWith specialised to zipping input streams of `A` and `B` into a `(A,B)` tuple stream
- `Concat[A]` - (2 inputs, 1 output) concatenates two streams (first consume one, then the second one)



Source: https://doc.akka.io/docs/akka/2.5.4/scala/stream/stream-graphs.html

Closed Shape

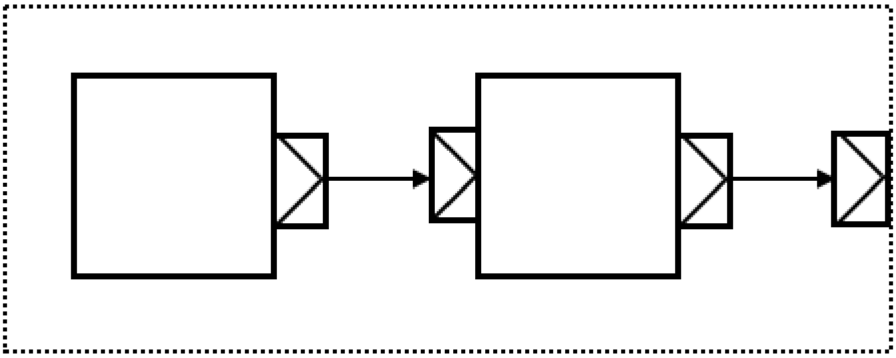
- Graph has all on ports accounted
- Nothing else can be connected
- Potential to be `RunnableGraph`



Source Shape

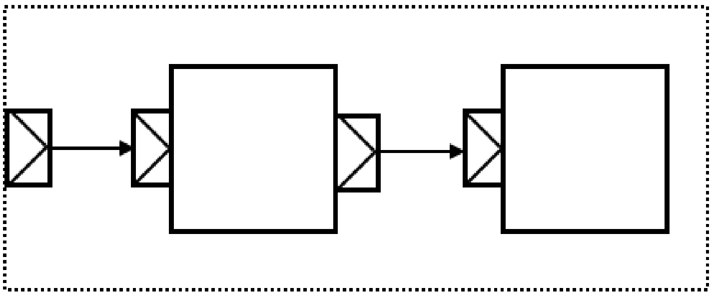
- Contains one open output port

- Requires other components to be closed and runnable



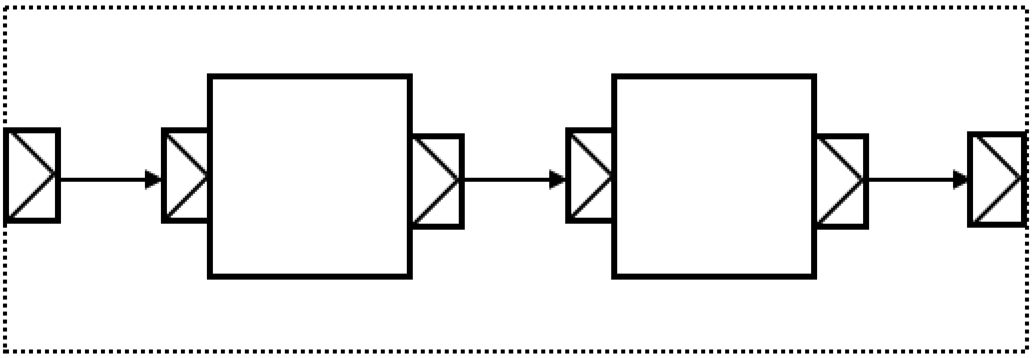
Sink Shape

- Contains one input shape, outputs are closed
- Requires other components to be closed and runnable



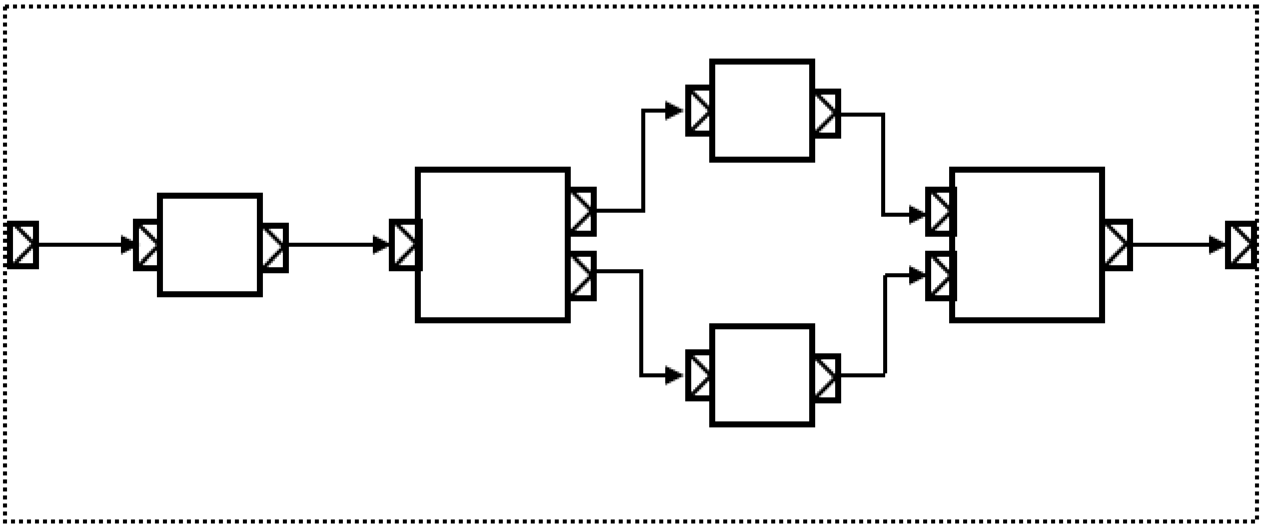
Flow Shape

- Contains one input, one output
- Composed of other components



Advanced Shapes

- All shapes can be complicated with more components
- You can determine how advanced or simple the graph can be



Constructing a Simple Graph

- The following graph has components constructed on the outside
  - `Source`
  - `Sink`
- `RunnableGraph.fromGraph` prepares the graph
- `builder` will allow us to plugin components to be used within the DSL
- `import GraphDSL.Implicits._` will allow DSL connectors like `~>`
- `ClosedShape` indicates the return shape, in this simple instance it is closed

```
val source = Source(1 to 100)
val sink = Sink.foreach[Int](println)

var runnableGraph: RunnableGraph[NotUsed] = RunnableGraph.fromGraph
(GraphDSL.create() {
      implicit builder =>
         import GraphDSL.Implicits._
         source ~> sink
         ClosedShape
    })

runnableGraph.run()
```

Creating a Denser Graph

- In the following Graph:
  - `outputToTwoFiles` is a composed `Graph` of a `Broadcast`
  - `Broadcat[Int](2)` states that there is one input and two output scheme
  - `int2ByteString` and `int2ByteString2` are flows that convert to `ByteString`
  - `ByteString` is wrapper to send `String` over the wire
  - This returns a `SinkShape`

```
val source = Source(1 to 100)

val outputToTwoFiles: Graph[SinkShape[Int], NotUsed] = GraphDSL.create()
{ implicit b =>
  import GraphDSL.Implicits._

  val fileSink1 = b.add(FileIO.toPath(Paths.get(s"
$userHome/complete1.txt")))
  val fileSink2 = b.add(FileIO.toPath(Paths.get(s"
$userHome/complete2.txt")))
  val int2ByteString1, int2ByteString2 = b.add(Flow[Int].map(x =>
ByteString(x)))
  val splitter = b.add(Broadcast[Int](2))

  splitter ~> int2ByteString1 ~> fileSink1.in
  splitter ~> int2ByteString2 ~> fileSink2.in

  SinkShape.apply(splitter.in)
}

source.runWith(outputToTwoFiles)
```

Lab: Running the graphs

Step 1: In the akka-streams-study project, and in the *src/test/scala* folder and in the *com.xyzcorp.akka.streams* package, locate the "Perform a test with an async boundary which will run on a separate actor and dispatcher" test in *GraphStreamSpec.scala*

Step 2: Run each method, in SBT, using the following which will only run the single test. Each test is labeled with the prefix "Case 1:", "Case 2:", "Case 3:" for ease

```
> testOnly com.xyzcorp.akka.streams.SimpleStreamSpec -- -z "Case 1:"
```

Step 3: Disassemble and discover types to understand how all of it fits together. Introduce explicit types to see how it all fits together and try different combinations

Kill Switches

Kill Switch

- A `Kill Switch` allows the programmer to:
  - complete the graph via `shutdown()`
  - fail the graph via `abort(Throwable t)`
- A `Kill Switch`
  - Can control the completion of one or multiple streams
  - Comes in two flavors:
    - `UniqueKillSwitch`
    - `SharedKillSwitch`

`UniqueKillSwitch`

- Always a result of a materialization using `viaMat`
- Allows to control and force the completion of one materialized `Graph` of `FlowShape` == Lab: `UniqueKillSwitch`

Step 1: In the akka-streams-study project, and in the *src/test/scala* folder and in the *com.xyzcorp.akka.streams* package, and in the *KillSwitchSpec* locate "Case 1", "Case 2" tests.

Step 2: Run the method, in SBT using the following which will only run the single test

```
> testOnly com.xyzcorp.akka.streams.KillSwitchSpec -- -z "Case 1"
```

```
> testOnly com.xyzcorp.akka.streams.KillSwitchSpec -- -z "Case 2"
```

Step 3: Disassemble and discover types to understand how all of it fits together. Introduce explicit types to see how it all fits together and try different combinations

Run and review *Case 1* and *Case 2* in the *KillSwitchSpec.scala* in *src/test/scala*

`SharedKillSwitch`

- Needs to be constructed before any materialization
- Controls the completion of an arbitrary number graphs of `FlowShape`
- It can be materialized multiple times via its `flow` method
- All materialized graphs linked to it are controlled by the switch

Lab: `SharedKillSwitch`

Step 1: In the akka-streams-study project, and in the *src/test/scala* folder and in the *com.xyzcorp.akka.streams* package, and in the *KillSwitchSpec* locate "Case 3", "Case 4" tests.

Step 2: Run the method, in SBT using the following which will only run the single test

```
> testOnly com.xyzcorp.akka.streams.KillSwitchSpec -- -z "Case 3"
```

```
> testOnly com.xyzcorp.akka.streams.KillSwitchSpec -- -z "Case 4"
```

Step 3: Disassemble and discover types to understand how all of it fits together. Introduce explicit types to see how it all fits together and try different combinations