Key Transforming Operators in the Flux Class (Part 2)

Douglas C. Schmidt
d.schmidt@vanderbilt.edu
www.dre.vanderbilt.edu/~schmidt

Professor of Computer Science

Institute for Software Integrated Systems

Vanderbilt University
Nashville, Tennessee, USA

Learning Objectives in this Part of the Lesson

- Recognize key Flux operators
  - Factory method operators
  - Transforming operators
    - Transform the values and/or types emitted by a Flux
      - e.g., flatMap()

Learning Objectives in this Part of the Lesson

- Recognize key Flux operators
  - Factory method operators
  - Transforming operators
    - Transform the values and/or types emitted by a Flux
      - e.g., flatMap()

```
return Flux
    .fromCallable(() -> BigFraction
        .reduce(unreducedFraction))

    .subscribeOn(scheduler)

    .flatMap(reducedFraction ->
             Flux
              .fromCallable(() ->
                 reducedFraction
                  .multiply
                    (sBigReducedFrac))
              .subscribeOn
                (scheduler));
```

This lesson also describes the Project Reactor flatMap() concurrency idiom

Key Transforming Operators in the Flux Class

Key Transforming Operators in the Flux Class

- The flatMap() operator
  - Transform the elements emitted by this Flux asynchronously

```
<R> Flux<R> flatMap
   (Function<? super T,
             ? extends Publisher<?
                        extends R>>
             mapper)
```

See projectreactor.io/docs/core/release/api/reactor/core/publisher/Flux.html#flatMap

Key Transforming Operators in the Flux Class

- The flatMap() operator
  - Transform the elements emitted by this Flux asynchronously
    - These elements are emitted into inner Publishers

```
<R> Flux<R> flatMap
  (Function<? super T,
            ? extends Publisher<?
                        extends R>>
            mapper)
```

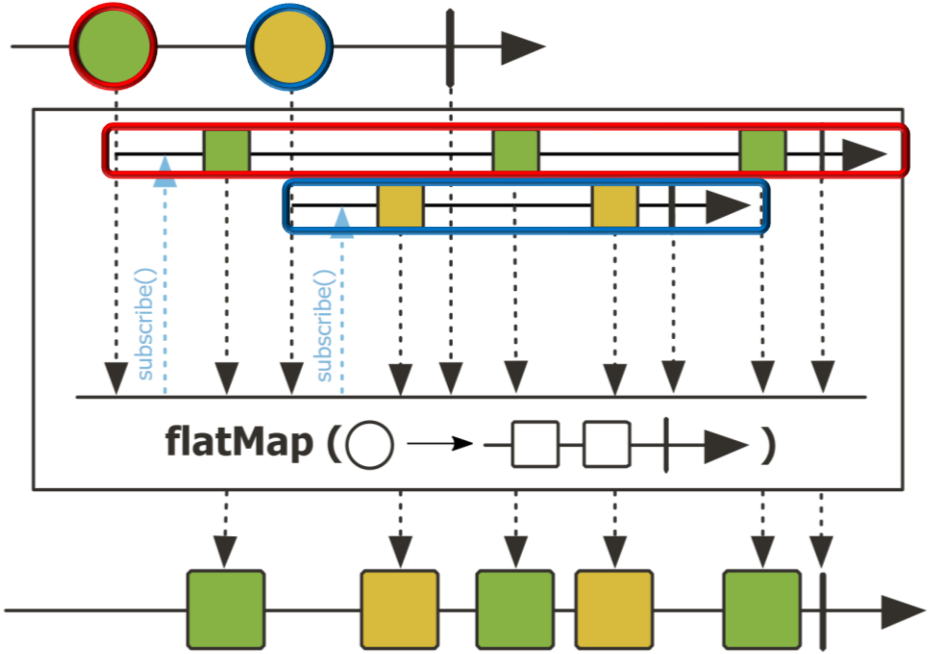
Key Transforming Operators in the Flux Class

- The flatMap() operator
  - Transform the elements emitted by this Flux asynchronously
    - These elements are emitted into inner Publishers
      - Each <T> input element is mapped to a Publisher<R>

```
<R> Flux<R> flatMap
  (Function<? super T,
            ? extends Publisher<?
                        extends R>>
            mapper)
```

Key Transforming Operators in the Flux Class

- The flatMap() operator
  - Transform the elements emitted by this Flux asynchronously
    - These elements are emitted into inner Publishers
      - Each <T> input element is mapped to a Publisher<R>
      - That publisher will emit one or more items



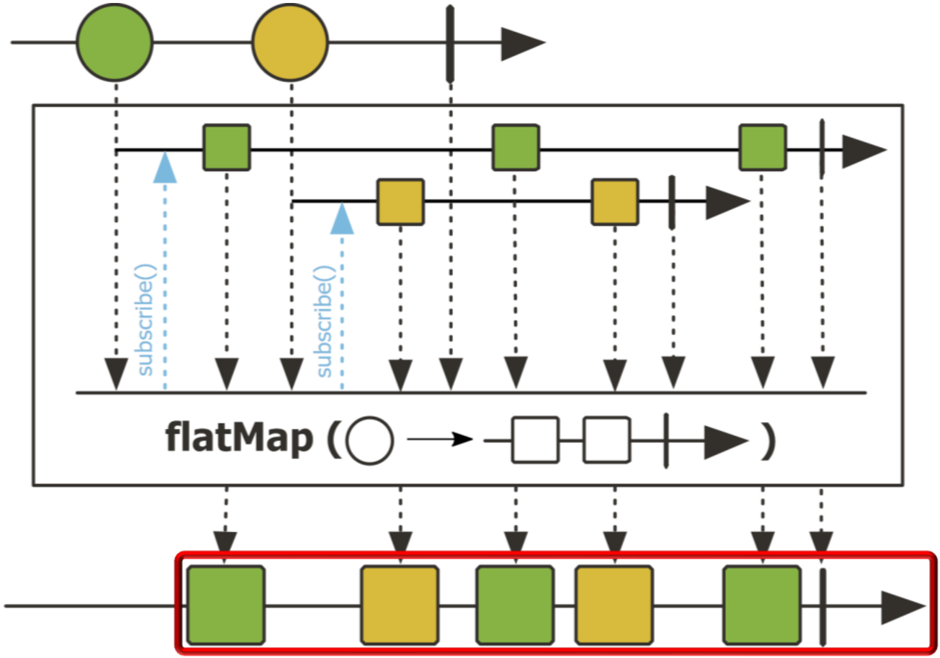
Key Transforming Operators in the Flux Class

- The flatMap() operator
  - Transform the elements emitted by this Flux asynchronously
    - These elements are emitted into inner Publishers
    - These inner publishers are then flattened into one Flux by merging

```
<R> Flux<R> flatMap
  (Function<? super T,
            ? extends Publisher<?
                        extends R>>
            mapper)
```

Key Transforming Operators in the Flux Class

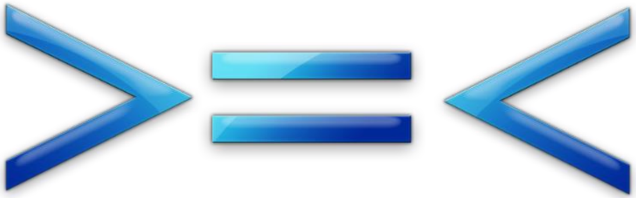
- The flatMap() operator
  - Transform the elements emitted by this Flux asynchronously
    - These elements are emitted into inner Publishers
    - These inner publishers are then flattened into one Flux by merging
      - They thus can interleave
        - Especially when used for concurrent processing

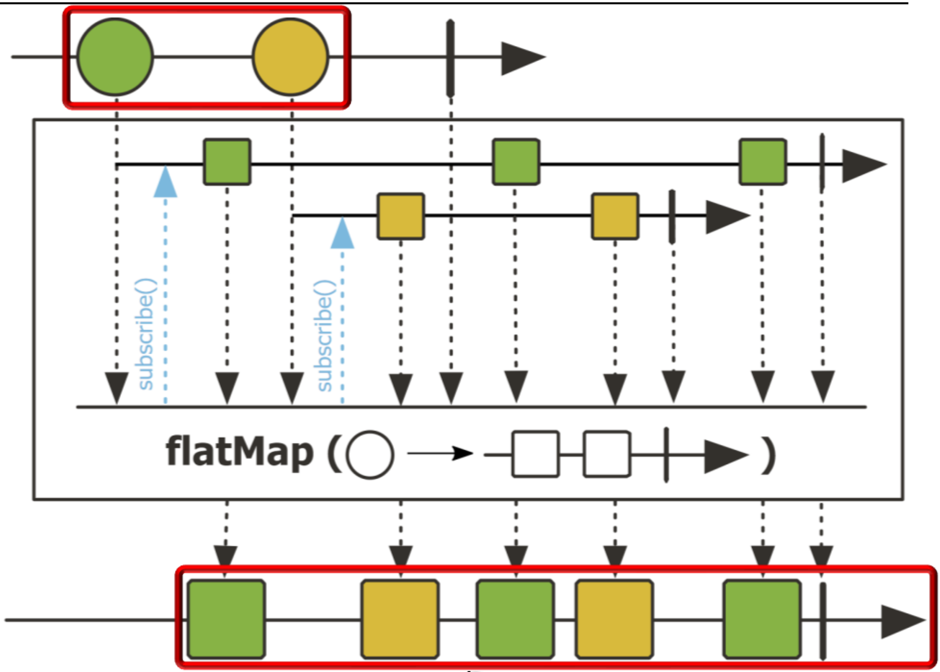


See upcoming walkthrough of the "flatMap() concurrency idiom" example

Key Transforming Operators in the Flux Class

- The flatMap() operator
  - Transform the elements emitted by this Flux asynchronously
    - These elements are emitted into inner Publishers
    - These inner publishers are then flattened into one Flux by merging
      - They thus can interleave

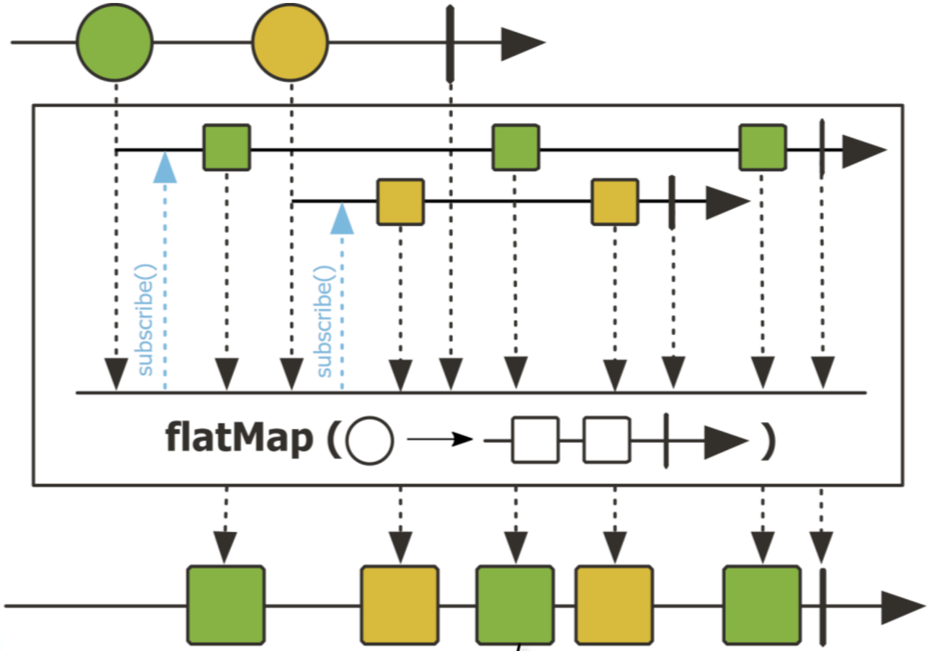




The # of output elements may differ from the # of input elements

Key Transforming Operators in the Flux Class

- The flatMap() operator
  - Transform the elements emitted by this Flux asynchronously
    - These elements are emitted into inner Publishers
    - These inner publishers are then flattened into one Flux by merging
      - They thus can interleave



flatMap() can transform the values and/or type of elements it processes

Key Transforming Operators in the Flux Class

- The flatMap() operator
  - Transform the elements emitted by this Observable asynchronously
  - This method is often used to trigger concurrent processing

```
return Flux
    .fromCallable(() -> BigFraction
        .reduce(unreducedFraction))

    .subscribeOn(scheduler)

    .flatMap(reducedFraction ->
             Flux
              .fromCallable(() ->
                 reducedFraction
                 .multiply
                   (sBigReducedFrac))
              .subscribeOn
                (scheduler));
```

See upcoming discussion on the Project Reactor flatMap() concurrency idiom

Key Transforming Operators in the Flux Class

- The flatMap() operator
  - Transform the elements emitted by this Observable asynchronously
  - This method is often used to trigger concurrent processing

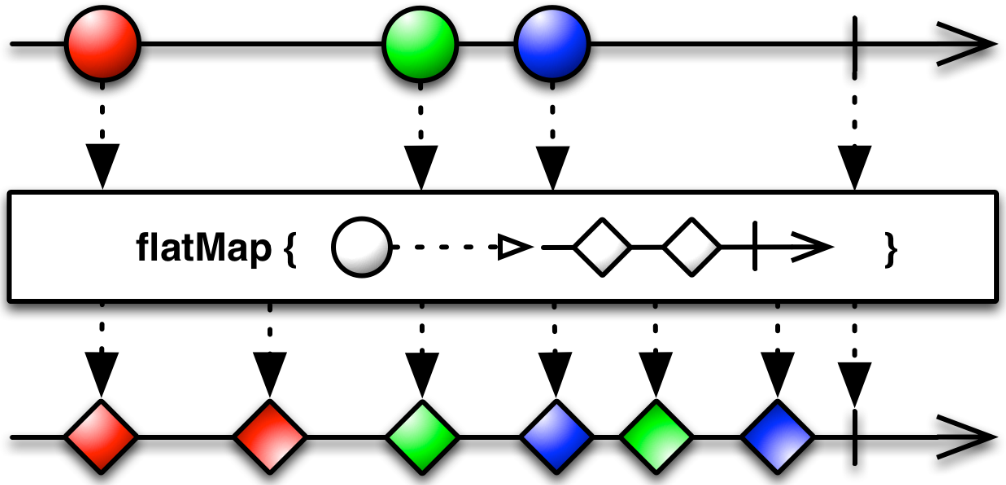
```
return Flux
  .fromCallable(() -> BigFraction
       .reduce(unreducedFraction))

  .subscribeOn(scheduler)

  .flatMap(reducedFraction ->
          Flux
           .fromCallable(() ->
              reducedFraction
               .multiply
                 (sBigReducedFrac))
           .subscribeOn
             (scheduler));
```

Return a Flux to a multiplied big fraction using the Project Reactor flatMap() concurrency idiom

See Reactive/flux/ex3/src/main/java/FluxEx.java

Key Transforming Operators in the Flux Class

- The flatMap() operator
  - Transform the elements emitted by this Flux asynchronously
  - This method is often used to trigger concurrent processing
  - RxJava's Observable.flatMap() method works the same way



See reactivex.io/RxJava/3.x/javadoc/io/reactivex/rxjava3/core/Observable.html#flatMap

Key Transforming Operators in the Flux Class

- The flatMap() operator
  - Transform the elements emitted by this Flux asynchronously
  - This method is often used to trigger concurrent processing
  - RxJava's Observable.flatMap() method works the same way
  - Similar to the Java Streams flatMap() operator

flatMap

```
<R> Stream<R> flatMap(
Function<? super T,? extends Stream<? extends R>> mapper)
```

Returns a stream consisting of the results of replacing each element of this stream with the contents of a mapped stream produced by applying the provided mapping function to each element. Each mapped stream is `closed` after its contents have been placed into this stream. (If a mapped stream is `null` an empty stream is used, instead.)

```
List<String> a = List.of("d", "g");
List<String> b = List.of("a", "c");
Stream
    .of(a, b)
    .flatMap(List::stream)
    .sorted()
    .forEach(System.out::println);
```

Flatten, sort, & print two lists of strings

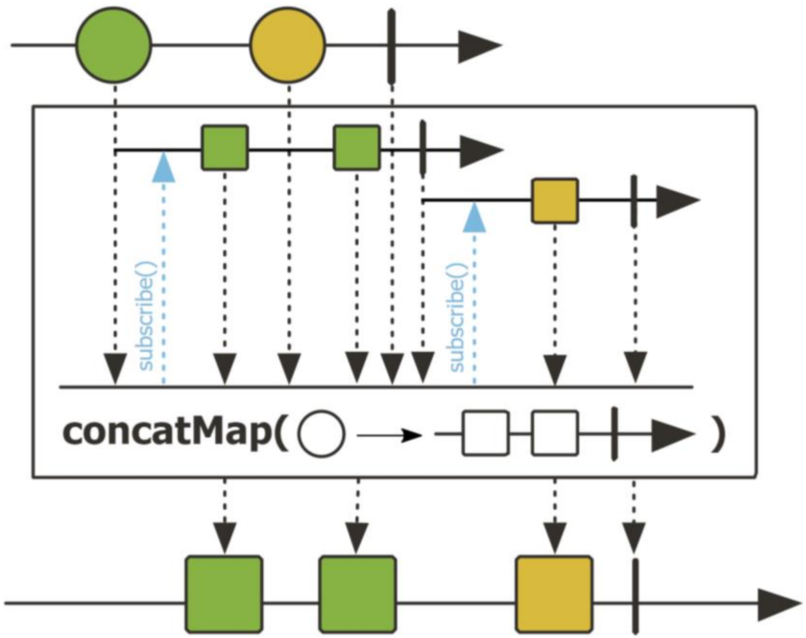
See docs.oracle.com/javase/8/docs/api/java/util/stream/Stream.html#flatMap

Key Transforming Operators in the Flux Class

- flatMap() doesn't guarantee the order of the items in the resulting stream

Key Transforming Operators in the Flux Class

- flatMap() doesn't guarantee the order of the items in the resulting stream
  - use concatMap() if order matters



See projectreactor.io/docs/core/release/api/reactor/core/publisher/Flux.html#concatMap

The Project Reactor flatMap() Concurrency Idiom

The Project Reactor flatMap() Concurrency Idiom

- flatMap()'s often used when each item emitted by a stream needs to apply its own threading operators


```
return Flux
   .fromIterable(bigFractions)

   .flatMap(bf -> Mono
             .fromCallable(() -> bf)
             .subscribeOn
                (Schedulers
                 .parallel())
             .map(multiplyBigFracs))

   .reduce(BigFraction::add)
   ...
```

The Project Reactor flatMap() Concurrency Idiom

- flatMap()'s often used when each item emitted by a stream needs to apply its own threading operators
  - This structure is known as the "flatMap() concurrency idiom"

```
return Flux
    .fromIterable(bigFractions)

    .flatMap(bf -> Mono
                .fromCallable(() -> bf)
                .subscribeOn
                   (Schedulers
                    .parallel())
                .map(multiplyBigFracs))

    .reduce(BigFraction::add)
    ...
```

See ebaytech.berlin/declarative-concurrency-with-reactor-70507e04054a

The Project Reactor flatMap() Concurrency Idiom

- flatMap()'s often used when each item emitted by a stream needs to apply its own threading operators
  - This structure is known as the "flatMap() concurrency idiom"

```
return Flux
    .fromIterable(bigFractions)

    .flatMap(bf -> Mono
                .fromCallable(() -> bf)
                .subscribeOn
                   (Schedulers
                    .parallel())
                .map(multiplyBigFracs))

    .reduce(BigFraction::add)
    ...
```

Create a Flux BigFraction stream from a BigFraction list

The Project Reactor flatMap() Concurrency Idiom

- flatMap()'s often used when each item emitted by a stream needs to apply its own threading operators
  - This structure is known as the "flatMap() concurrency idiom"

```
return Flux
    .fromIterable(bigFractions)

    .flatMap(bf -> Mono
             .fromCallable(() -> bf)
             .subscribeOn
                (Schedulers
                 .parallel())
             .map(multiplyBigFracs))

    .reduce(BigFraction::add)
    ...
```

Iterate thru the Flux stream multiplying big fractions in the parallel thread pool

See Reactive/flux/ex3/src/main/java/FluxEx.java

The Project Reactor flatMap() Concurrency Idiom

- flatMap()'s often used when each item emitted by a stream needs to apply its own threading operators
  - This structure is known as the "flatMap() concurrency idiom"

```
return Flux
   .fromIterable(bigFractions)

   .flatMap(bf -> Mono
             .fromCallable(() -> bf)
             .subscribeOn
                (Schedulers
                 .parallel())
             .map(multiplyBigFracs))

   .reduce(BigFraction::add)
   ...
```

Each BigFraction in the stream is processed concurrently in the parallel thread pool

The Project Reactor flatMap() Concurrency Idiom

- flatMap()'s often used when each item emitted by a stream needs to apply its own threading operators
  - This structure is known as the "flatMap() concurrency idiom"

```
return Flux
   .fromIterable(bigFractions)

   .flatMap(bf -> Mono
                  .fromCallable(() -> bf)
                  .subscribeOn
                     (Schedulers
                       .parallel())
                  .map(multiplyBigFracs))

   .reduce(BigFraction::add)
   ...
```

Emit each BigFraction in the "inner publisher"

The Project Reactor flatMap() Concurrency Idiom

- flatMap()'s often used when each item emitted by a stream needs to apply its own threading operators
  - This structure is known as the "flatMap() concurrency idiom"

```
return Flux
   .fromIterable(bigFractions)

   .flatMap(bf -> Mono
              .fromCallable(() -> bf)
              .subscribeOn
                 (Schedulers
                  .parallel())
              .map(multiplyBigFracs))

   .reduce(BigFraction::add)
   ...
```

Arrange to process each emitted BigFraction in the parallel thread pool

The Project Reactor flatMap() Concurrency Idiom

- flatMap()'s often used when each item emitted by a stream needs to apply its own threading operators
  - This structure is known as the "flatMap() concurrency idiom"

```
return Flux
    .fromIterable(bigFractions)

    .flatMap(bf -> Mono
                 .fromCallable(() -> bf)
                 .subscribeOn
                    (Schedulers
                     .parallel())
                 .map(multiplyBigFracs))

    .reduce(BigFraction::add)
    ...
```

Multiply each BigFraction in a thread from the parallel thread pool

The Project Reactor flatMap() Concurrency Idiom

- flatMap()'s often used when each item emitted by a stream needs to apply its own threading operators
  - This structure is known as the "flatMap() concurrency idiom"

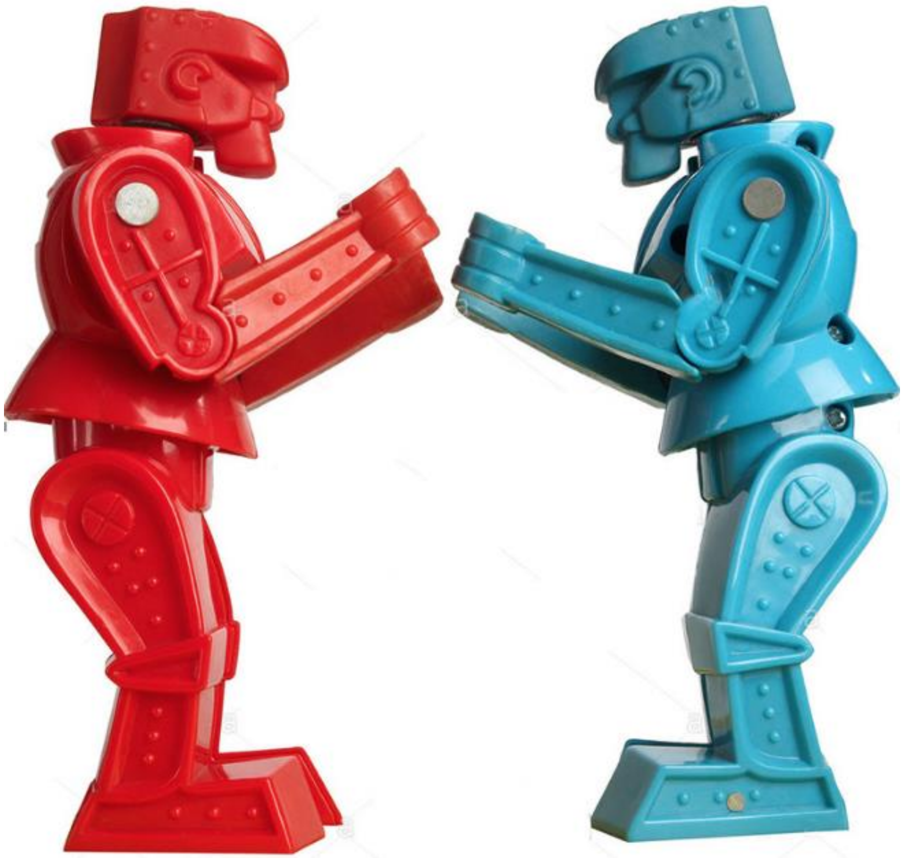
After all the concurrent processing completes then add all the Big Fractions to compute the final sum

```
return Flux
   .fromIterable(bigFractions)

   .flatMap(bf -> Mono
                .fromCallable(() -> bf)
                .subscribeOn
                   (Schedulers
                    .parallel())
                .map(multiplyBigFracs))

   .reduce(BigFraction::add)
   ...
```

Comparing map & flatMap()

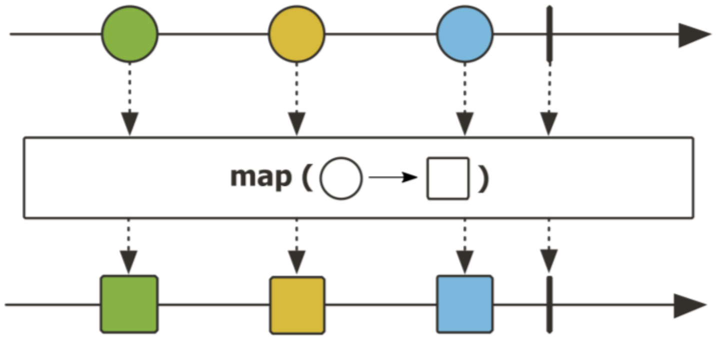
Comparing map() & flatMap()

- The map() vs. flatMap() operators



Comparing map() & flatMap()

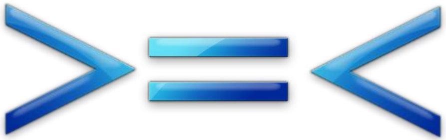
- The map() vs. flatMap() operators
  - The map() operator transforms each value in a Flux stream into a single value
    - i.e., intended for synchronous, non-blocking, 1-to-1 transformations

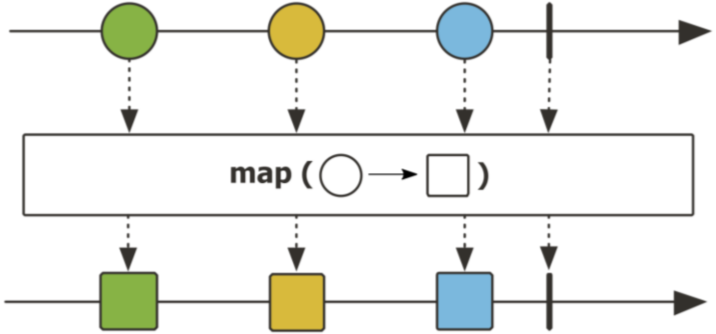


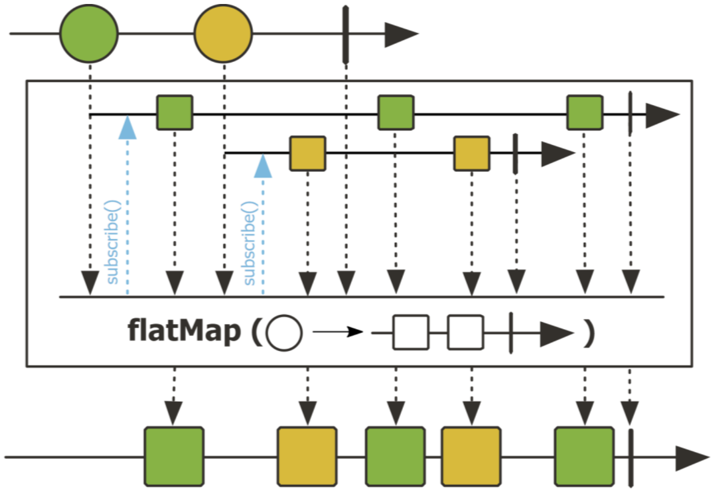
See stackoverflow.com/questions/49115135/map-vs-flatmap-in-reactor

Comparing map() & flatMap()

- The map() vs. flatMap() operators
  - The map() operator transforms each value in a Flux stream into a single value
  - The flatMap() operator transforms each value in a Flux stream into an arbitrary number (zero or more) values
    - i.e., intended for asynchronous (often non-blocking) 1-to-N transformations







See stackoverflow.com/questions/49115135/map-vs-flatmap-in-reactor

End of Key Transforming Operators in the Flux Class (Part 2)