Java & Spring
Reactive Programming

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Introduction

Reactive Programming

"is a declarative programming paradigm concerned with data streams and the propagation of change" (wiki)

Introduction

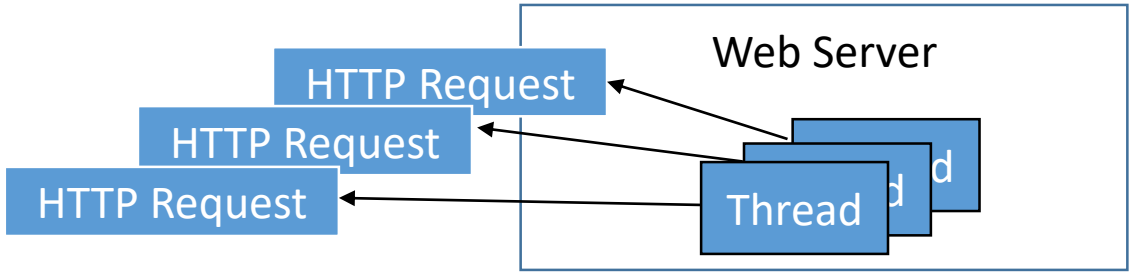
What is the problem with current programming?

- In order to understand it clearly – let's take a look at how traditional web servers works today:
  - Based on request-response mechanism
    - Responses are packed at-once
    - Server architecture is 'Request-based'

Introduction

Request-Based causes back pressure

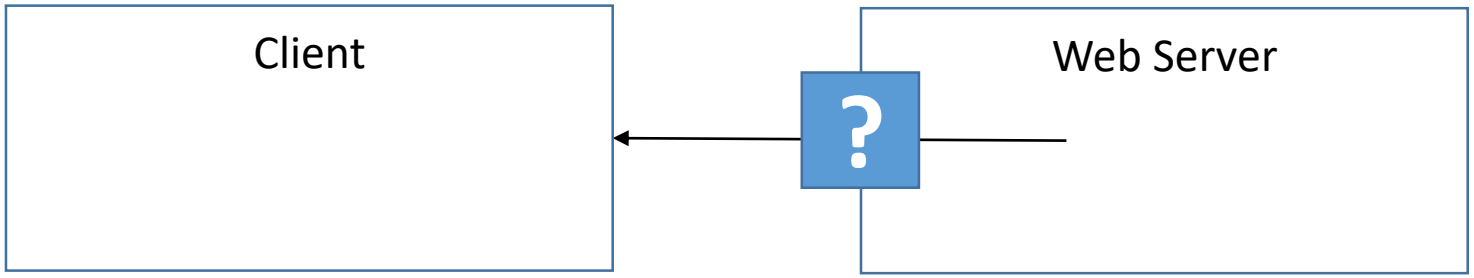
- Threads are consumed according to requests – ‘Request Oriented’ mechanism
- Each thread is usually dedicated to the request until completed
- This can cause lot of requests wait for hosting threads
- In high and intense concurrencies clients end up with timeouts
- Client capability of processing responses in not counted



Introduction

Response at-once makes data streaming hard

- Clients may have to handle lots of data
  - No one asks the client how much ‘response’ it can handle….
  - No way for clients to specify it in a built-in manner
- HTTP 1 tricks for streaming
  - Client refresh (intensive requests, repeatable data)
  - Response flushing (suffers from timeouts)
  - Web-sockets (performs badly)



Introduction

The Reactor Design Pattern

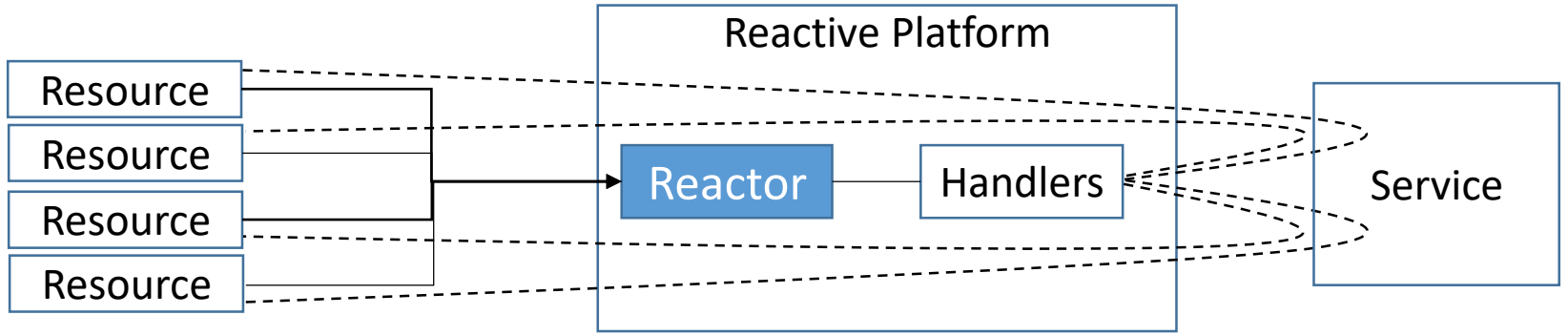
An implementation technique of event driven model

- Mostly, uses single dispatcher thread event-loop blocking on resources I/O requests (clients)
- Resources emits events which are sequentially dispatched by the thread to handlers
- Events might be:
  - new connection
  - ready for read
  - ready for write
  - timeout
  - disconnecting
- Handlers (or callbacks) performs the actual work in a non-blocking manner
  - doesn’t block the dispatcher thread

Introduction

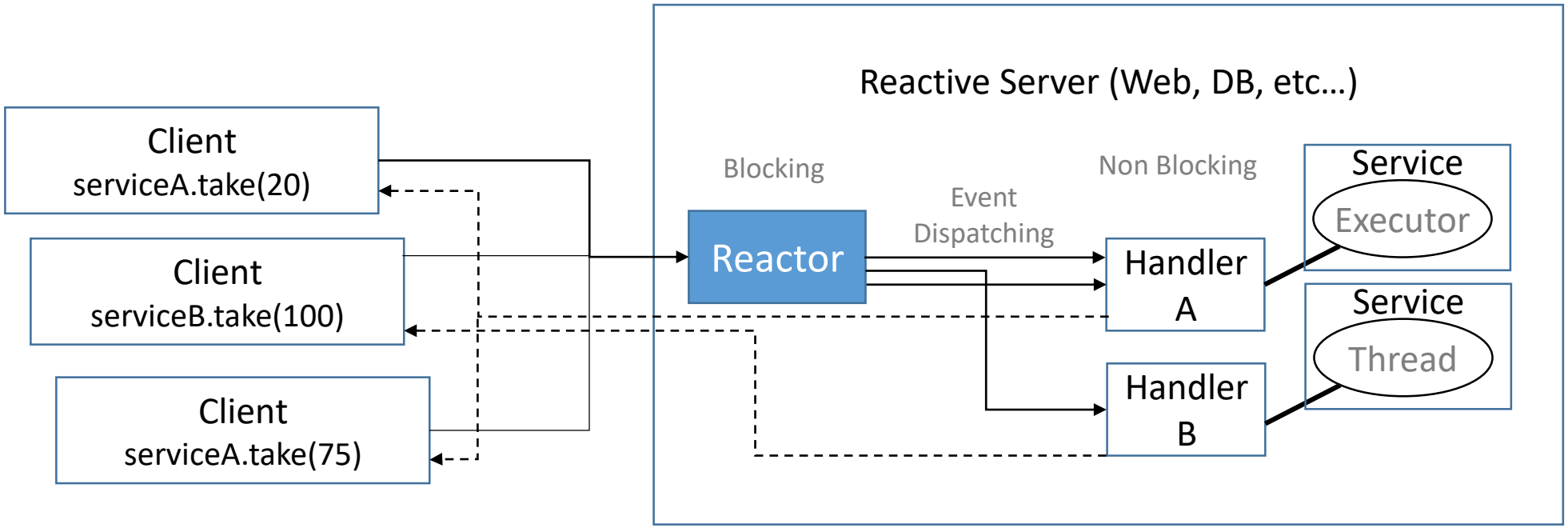
The Reactor Design Pattern

- Reactive system has one input and multiple outputs
  - Decouples application-level code from reusable reactor
  - Reactor is like an operator that accepts client calls and forwards it to the appropriate extension
- De-multiplexed services
  - Clients can split requests in order to receive responses in appropriate timing & sizes
  - Work <u>is not</u> done in a “Thread per request” manner – work is distriburted to subsystems via handlers



Introduction

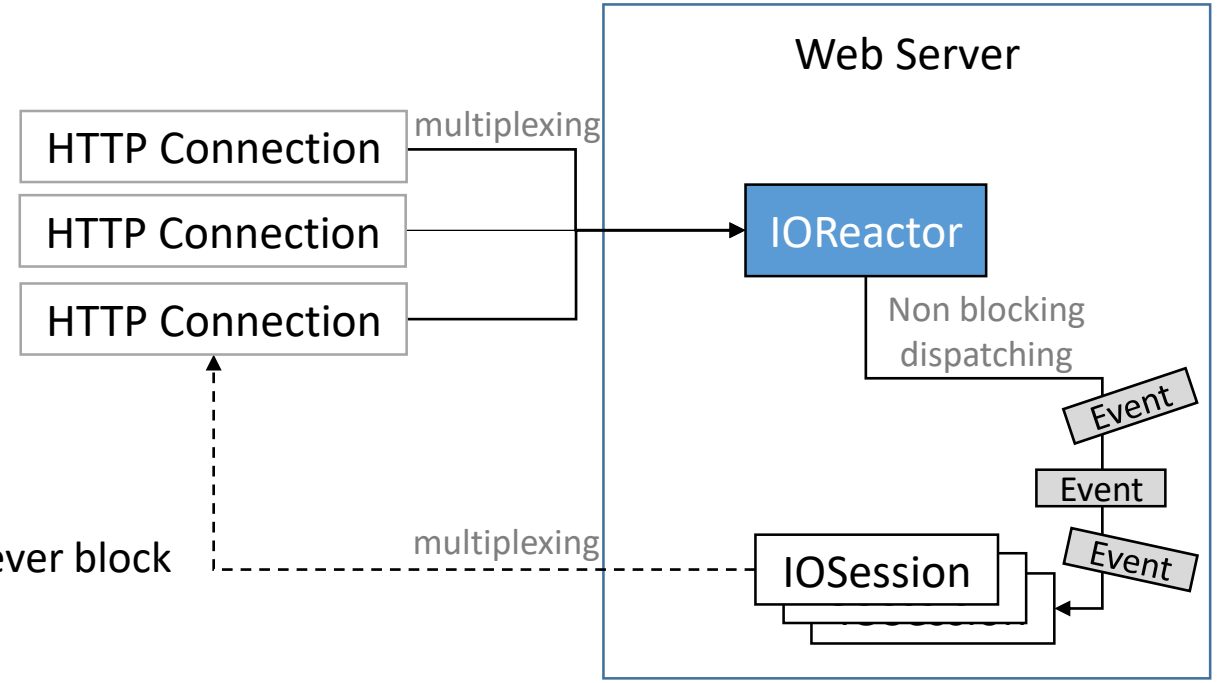
The Reactor Design Pattern



Introduction

Java HttpCore NIO Reactor Platform

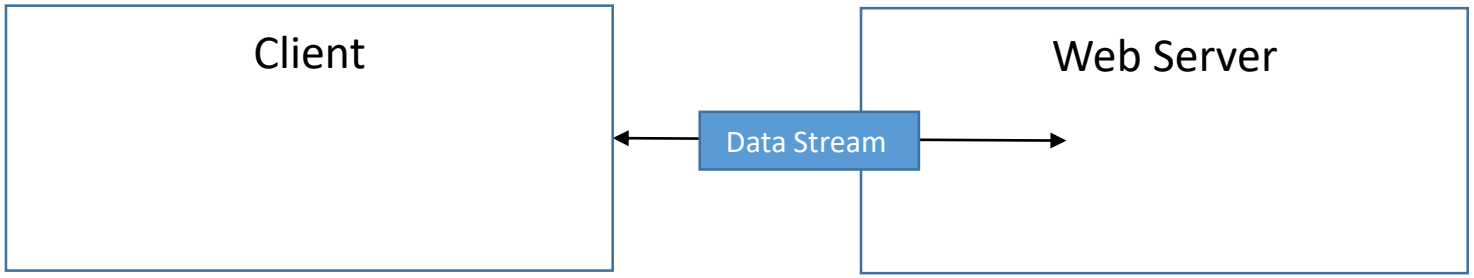
- IOReactor
  - Is the dispatcher
  - Uses several threads
  - Uses multiplexing (selectable channel)
  - Recommended: one IOReactor per CPU
  - May listen to several ports
  - Can be shutdown
- IOEventDispatch
  - Is the event delegated to registered handlers
  - Triggered by IOReactor thread(s) – so should never block
- IOSession
  - Is an handler capable of reading and writing from and to clients
  - Sessions stores continuous data internally – NOT in any thread context (!)
  - Uses non-blocking I/O as well (selectable channels)
  - Can be shutdown



Introduction

Reactive programming benefits

- Preventing back pressure
- Data streaming over HTTP2
- Using few threads effectively (no blocks)
- Simple asynchronous modelling
- Handling client request in a pipeline manner



Introduction

Reactive Programming Evolution in Java

- Java 7 – ForkJoin
  - Executor which supports recursive tasks
- Java 8 – CompletableFuture & Functional programming
  - Future result can be used for further manipulation in the same or alterative thread pool
- Java 9 – Flow API - RxJava

Java Flow API

Java Flow API

Java 9 adds the core infrastructure for reactive programming

- Flow – unit that processes events and encapsulates concurrency
- Subscriber – event endpoint
- Publisher – generates events and publishes to registered subscribers
- Processors – subscribing interceptors (for creating subscription chain)

Java Flow API

Subscriber

- Subscriber supports data subscription over reactive platforms
- Defines methods for reactive subscrition
  - onComplete()
  - onError(Throwable t)
  - onNext()
  - onSubscribe()

Java Flow API

Publisher

- Publisher supports registering subscribers for consuming data over reactive platforms
  - Subscribe(Subscriber<T> sub)
  - Extends Subscriber. Publishers are also Subscribers

- Subscriber events
  - onSubscribe() – after calling Publisher.subscribe(Subscriber s)
  - onNext() – notifies Subscription.request(long)

Java Flow API

Steps in creating reactive application:

- Create a Flow.Publisher
- Register Flow.Subscribers via Publisher.subscribe()
- Implement Subscriber to handle events:
  - onSubscribe()
  - onNext()
  - onError()
  - onComplete()
- Use Publisher to generate events

- Flow acts like a Pipe here – passing events from publisher to the ‘Sink’ side – the Consumer
- BUT –unlike pipes - it uses Executor, the daemon common pool (ForkJoin)

Java Flow API

- When creating Publisher
  - Default constructor uses common pool (Fork-Join daemon pool)
  - Alternative executors may be used instead
  - This is how all thread complexity remains hidden

- Multiple subscribers may be registered to a single Publisher
  - Use publisher.subscribe()

```
//Create Publisher (works with common-pool)
SubmissionPublisher<String> publisher = new SubmissionPublisher<>();

// Create Publisher with dedicated pool
Executor e=Executors.newFixedThreadPool(3);
SubmissionPublisher<String> publisher = new SubmissionPublisher<>(e);
```

Java Flow API

Subscriber

```
  public class MySubscriber<T> implements Subscriber<T> {
       private Subscription subscription;
       @Override
       public void onSubscribe(Subscription subscription) {
         this.subscription = subscription;
       }
       @Override
       public void onNext(T item) {
         subscription.request(1); //Long.MAX_VALUE may be considered as unbounded
       }
       @Override
       public void onError(Throwable t) {
         t.printStackTrace();
       }
       @Override
       public void onComplete() {
         System.out.println("Done");
       }
}
```

Java Flow API

Publishing messages

- Use publisher.submit(T)
- Each registered Subscriber get its own instance of Subscription

```
//Create Publisher
SubmissionPublisher<String> publisher = new SubmissionPublisher<>();

//Register Subscriber
MySubscriber<String> subscriber = new MySubscriber<>();
publisher.subscribe(subscriber);

//Publish messages
String[] items = {"msg1", "msg2", "msg3"};
Arrays.asList(items).stream().forEach(publisher::submit);
```

Java Flow API

Processors

- Enhanced subscribers
- While subscribers acts as endpoints, processors delegates messages
- Processor uses Function<T,R> to process messages
  - Incoming message is T
  - Outgoing message is R (which might be T as well..)

Java Flow API

Processors *example*

```
public class Processor1<T,R> extends SubmissionPublisher<R> implements Processor<T, R> {

  private Function<? super T, ? extends R> function;
  private Subscription subscription;

  public MyTransformProcessor(Function<? super T, ? extends R> function) {
    super();
    this.function = function;
  }
  @Override
  public void onSubscribe(Subscription subscription) {
    this.subscription = subscription;
  }
  @Override
  public void onNext(T item) {
    submit((R) function.apply(item));
    subscription.request(1);
  }…
```

Java Flow API

Processors

- Now we can define a subscription chain
- This is haw we split asynchronous tasks while using thread pools

```
SubmissionPublisher<String> publisher = new SubmissionPublisher<>();
MySubscriber<Integer> subscriber = new MySubscriber<>();

//Creating Midpoints Processors
Processor1<String, String> p1 =
    new Processor1<>(s -> {if(s.equals("msg1"))return “100"; return “200";});
Processor1<String, Integer> p2 =
    new Processor1<>(s -> Integer.parseInt(s));

//Configuring subscription chain
publisher.subscribe(p1);
p1.subscribe(p2);
p2.subscribe(subscriber);
```

Java Flow API

Signal

- Publishers supports Signal consumption
- Consumer<Signal> may check signal type and take action
- Signal is fired when publisher generates notification and supports:
  - isOnSubscribe()
  - isOnError()
  - isOnNext()
  - isOnComplete()

SignalType Enum

- AFTER_TERMINATE
- CANCEL
- ON_COMPLETE
- ON_ERROR
- ON_NEXT
- ON_SUBSCRIBE
- REQUEST

Spring Reactive Programming

Spring Reactive Programming

- Spring WebFlux
- Provides abstraction which supports
  - RxJava
  - ReactiveX
  - Reactor

- Docs: *https://projectreactor.io/docs*

Spring Reactive Programming

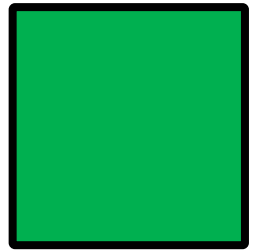
- SpringBoot
  - Minimum major version 2.0.*
  - Select dependency: Reactive Web
    - Spring WebFlux
    - 

  - WebFlux Meven dependency:

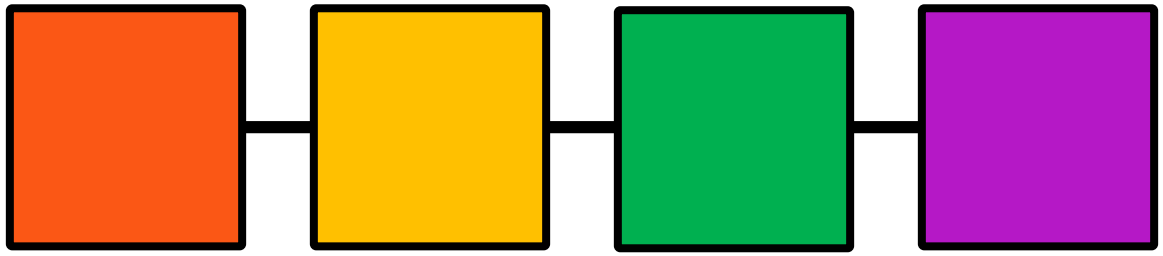
```
<dependency>
        <groupId>org.springframework.boot</groupId>
        <artifactId>spring-boot-starter-webflux</artifactId>
</dependency>
```

Publishers (& Subscribers)

- Spring publishers:
  - Mono – for single item subscription
  - Flux – for multiple items

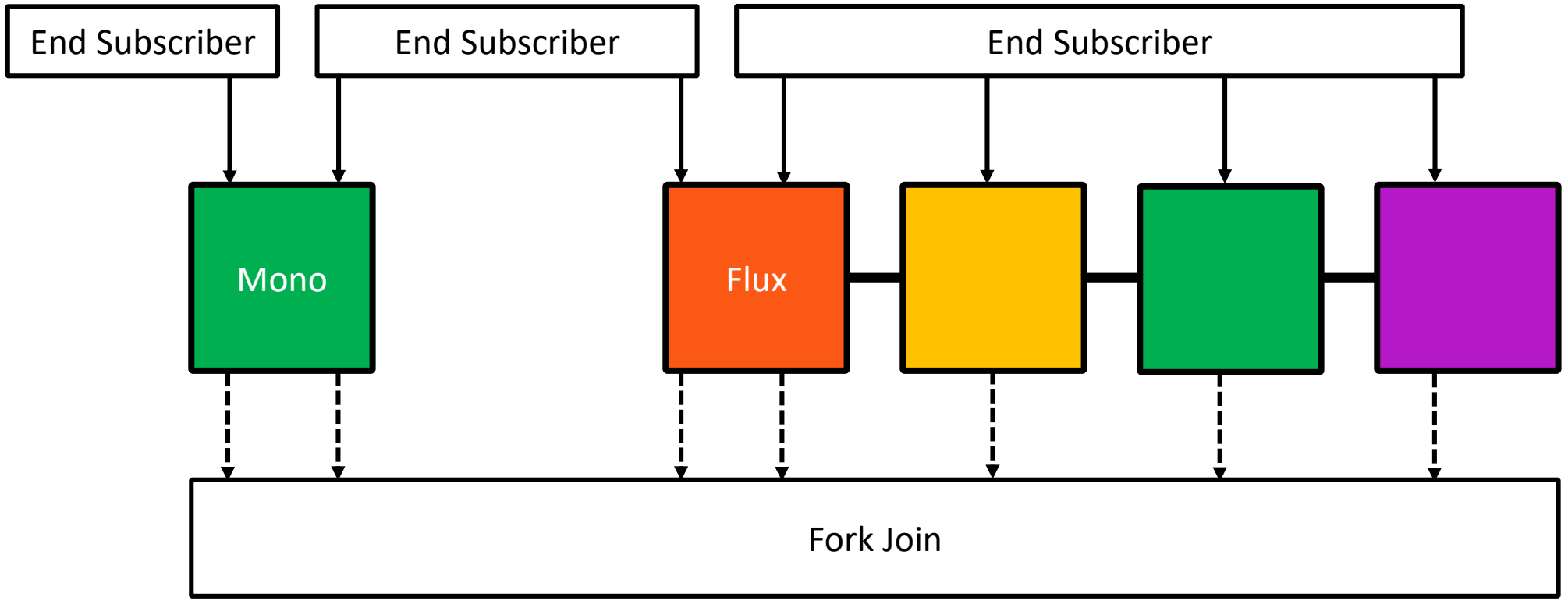


  - Offers rich set of stream consumption functionality



Publishers (& Subscribers)

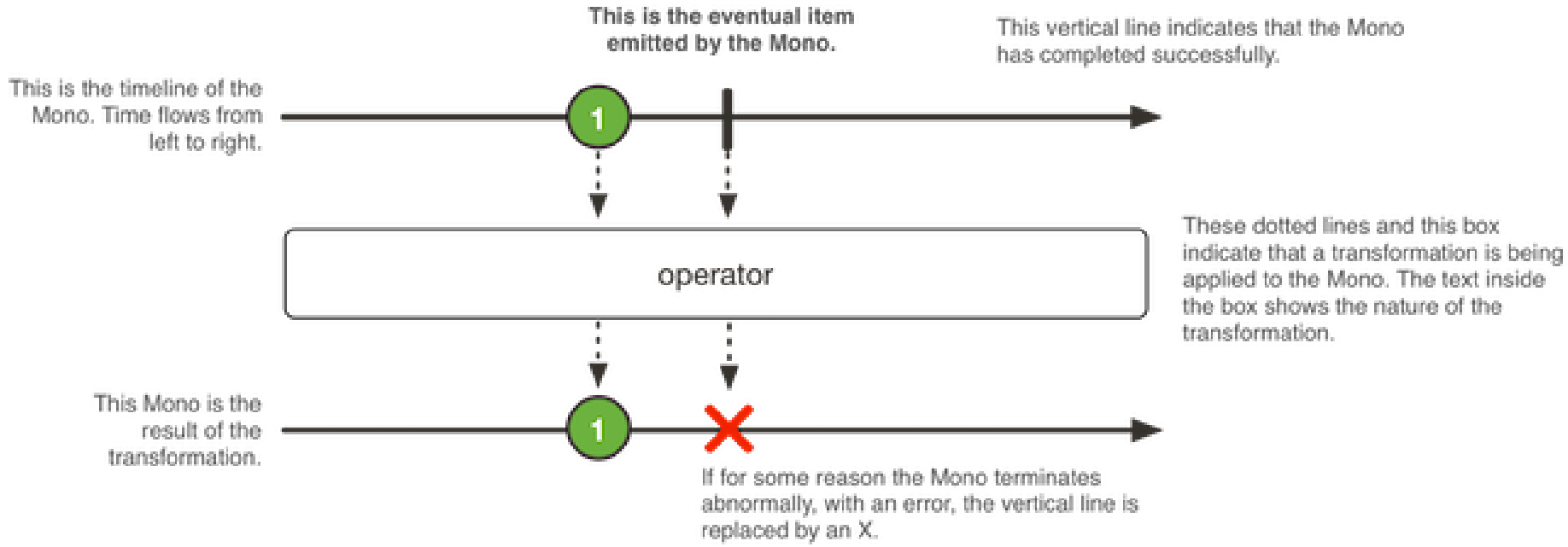
- Reactive Platform:



Mono

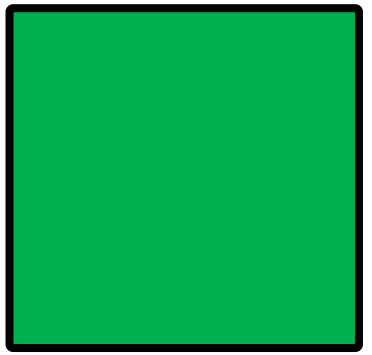
Mono

- For emitting:
  - Nothing
  - Single value
  - Error



Mono

- Creating Mono via static methods:
  - create(Consumer<Sink<T>> callback)
    - creates Mono<R> using Consumer<T>
    - Sink<T> is basically a kind of stream supplier
      - success() & error() constructs Mono<T>/Mono<Ex>
      - listeners may be attached



Mono

- Example:
  - create(Consumer<Sink<T>> callback)

```
public Mono<String> monoCreate(String value){
    return Mono.create(sink->{
          if(value.length()<10) {
                    String response="Hello "+value+" !";
                    sink.success(response);
          }else
                    sink.error(new Exception("value ("+value+") is too long"));
          });
}
```

```
System.out.println("Mono Create: "+ex.monoCreate("David").block());
```

```
Mono Create: Hello David !
```

Mono

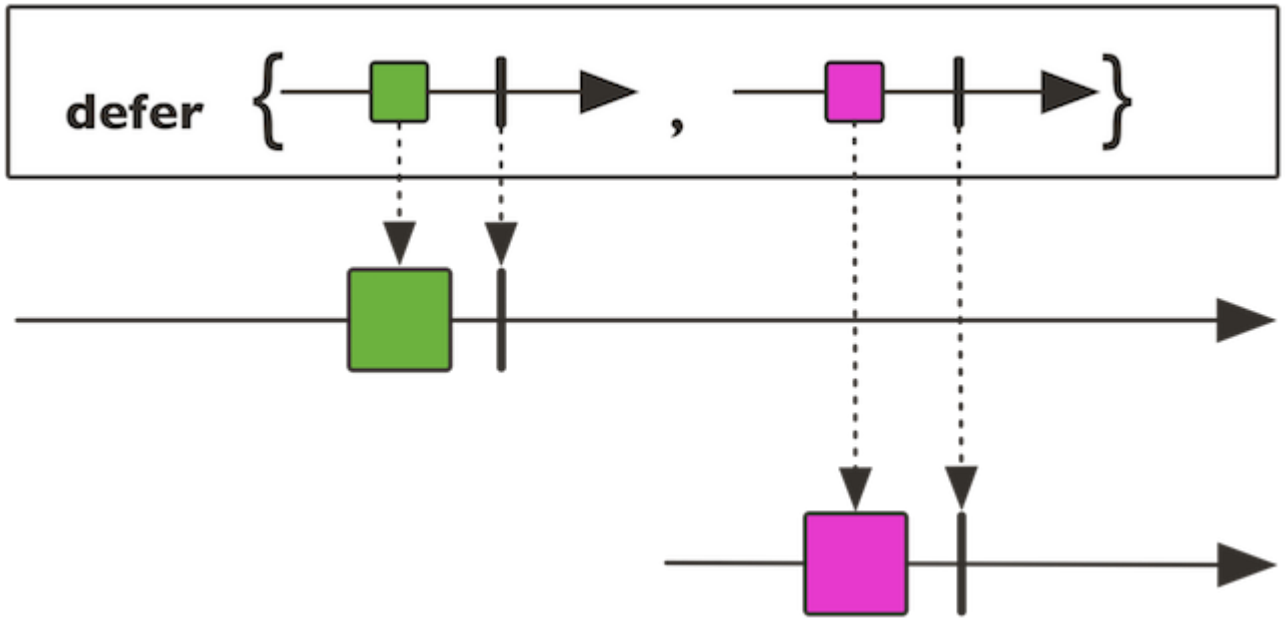
- Example:
  - create(Consumer<Sink<T>> callback)

```
// argument is too long and should lead to Mono.create error
System.out.println("Mono Create: "+ex.monoCreate("David12345").block());
```

```
Exception in thread "main" reactor.core.Exceptions$ReactiveException: java.lang.Exception: value (David12345) is too long
        at reactor.core.Exceptions.propagate(Exceptions.java:326)
        at reactor.core.publisher.BlockingSingleSubscriber.blockingGet(BlockingSingleSubscriber.java:91)
        at reactor.core.publisher.Mono.block(Mono.java:1175)
        at react.Application.mono(Application.java:50)
        at react.Application.main(Application.java:25)
        Suppressed: java.lang.Exception: #block terminated with an error
```

Mono

- Creating Mono via static methods:
  - defer(Supplier<Mono<T>> mono)
    - creating Mono<Mono<T>> which supplies target Mono<T>



Mono

- Example:
  - defer(Supplier<Mono<T>> mono)

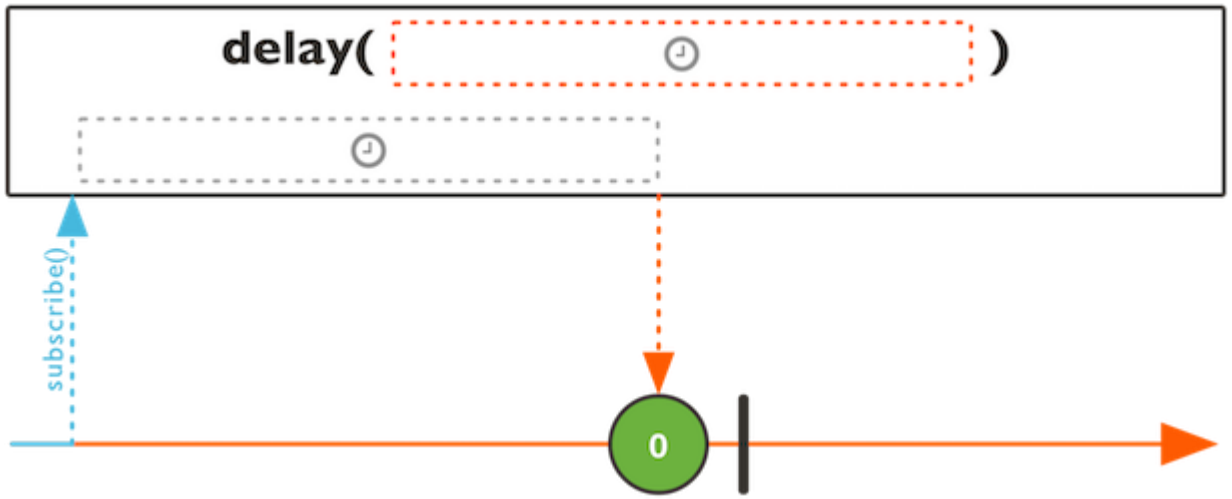
```
//here we use previous method as a Mono<String> Supplier
public Mono<String> monoDefer(String value){
          return Mono.defer(()->monoCreate("- "+value));
}
```

```
System.out.println("Mono Defer: "+ex.monoDefer(“Eve").block());
```

```
Mono Create: Hello - Eve !
```

Mono

- Creating Mono via static methods:
  - delay(Period period)
  - delay(Period period, Scheduler timer)
    - creates Mono which completes after given delay and returns zero as Mono<Long>



Mono

- Example:
  - delay(...)

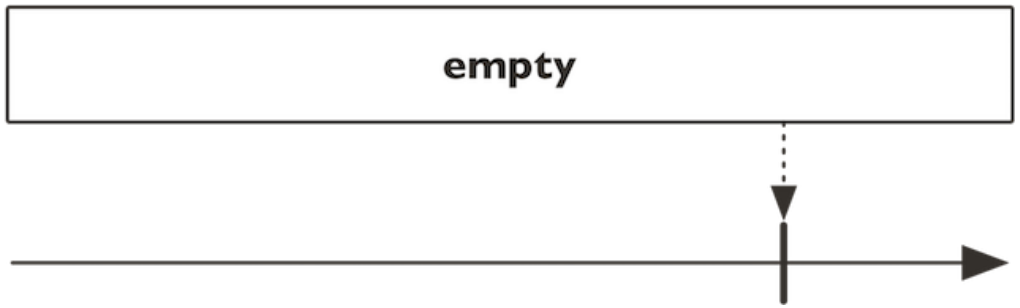
```
public Mono<Long> monoDelay(int sec){
          return Mono.delay(Duration.ofSeconds(sec));
}
```

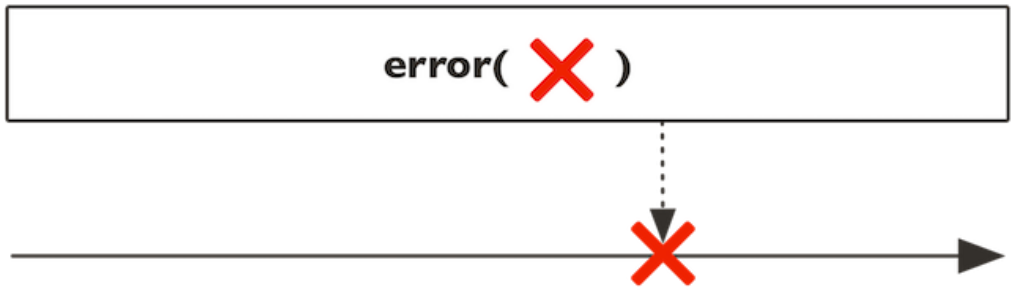
```
System.out.println("Mono Delay: "+ex.monoDelay(“Eve").block());
```

```
Mono Delay: 0
```

Mono

- Creating Mono via static methods:
  - empty()
    - creates empty Mono – returns Mono<Void>
  - error(Throwable error)
    - creates error Mono – returns Mono<Throwable>





Mono

- Example:
  - empty(...)

```
public Mono<?> monoEmpty(int sec){
          return Mono.empty();
}
```

```
System.out.println("Mono Empty: "+ex.monoEmpty().block());
```

```
Mono Empty: null
```

Mono

- Example:
  - error(...)

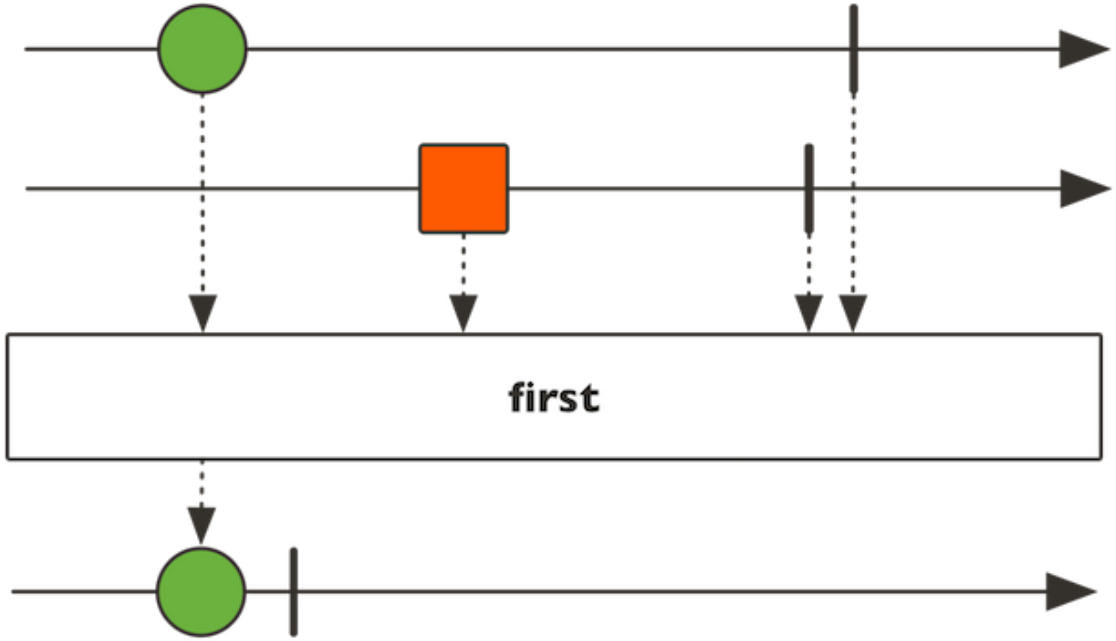
```
public Mono<Throwable> monoError(String errMsg){
          return Mono.error(new Exception(errMsg));
}
```

```
System.out.println("Mono Error: "+ex.monoError(“Some Error”).block());
```

```
Exception in thread "main" reactor.core.Exceptions$ReactiveException: java.lang.Exception: Some Error
          at reactor.core.Exceptions.propagate(Exceptions.java:326)
          at reactor.core.publisher.MonoError.block(MonoError.java:48)
          at react.Application.mono(Application.java:54)
          at react.Application.main(Application.java:25)
Caused by: java.lang.Exception: Some Error
          at react.examples.MonoReactiveExamples.monoError(MonoReactiveExamples.java:39)
          ... 2 more
```

Mono

- Creating Mono via static methods:
  - first(Iteratable<Mono<T>> monos)
  - first(Mono<T>… monos)
    - returns first completed Mono<T>



Mono

- Example:
  - first(...)

```
public Mono<?> monoFirst(int sec){
          Mono.first(monoDelay(1),monoCreate("Create"),monoJust("Just"));
}
```

```
System.out.println("Mono First: "+ex.monoFirst().block());
```

```
Mono First: Hello Create !
```

Mono

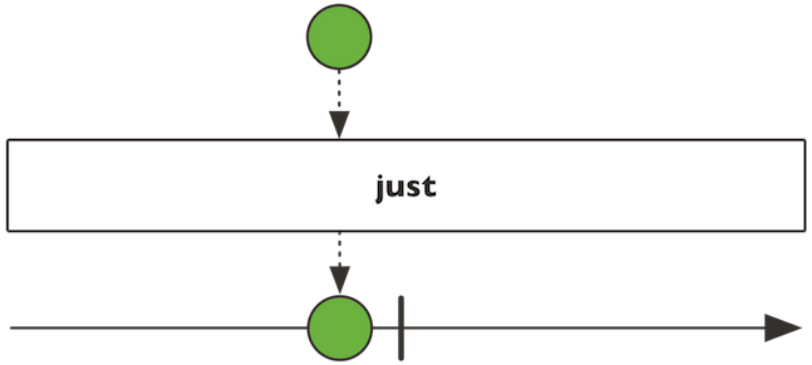
- Creating Mono via static methods:

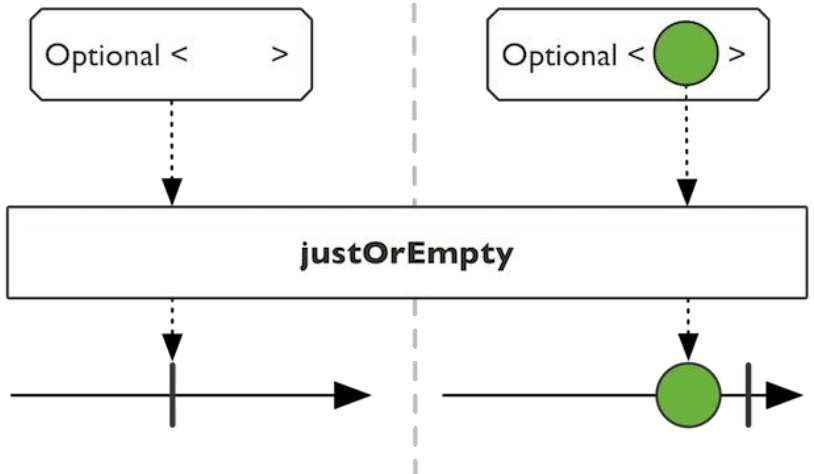
- Mono<T> factoring methods for supporting JSE, Flow, Concurrent APIs:

  - from(Publisher<T> publisher)
  - fromCallable(Callable<T> task)
  - fromCompletionStage(CompletionStage<T> stage)
  - fromFuture(Future<T> taskResult)
  - fromRunnable(Runnable task) – returns Mono<Void>
  - fromSupplier(Supplier<T> supplier)

Mono

- Creating Mono via static methods:
  - just(T data)
    - returns Mono<T>, data might be null
  - justOrEmpty(Optional<T> optional)
    - return Mono<T> only if optional.isPresent()==true, otherwise completes (onComplete)
  - justOrEmpty(T data)
    - return Mono<T> only if data is not NULL, otherwise completes (onComplete)





Mono

- Example:
  - just(...)

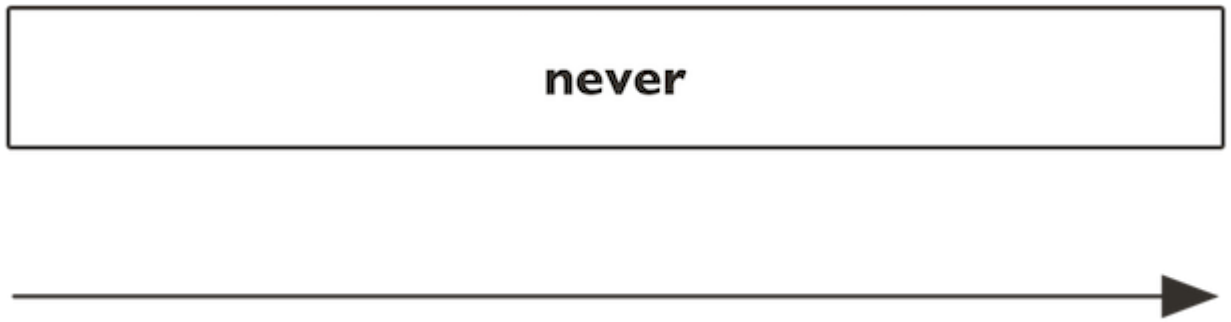
```
public Mono<String> monoJust(String data){
     return Mono.just(data);
}
```

```
System.out.println("\nMono Just: "+ex.monoJust("Just..").block());
```

```
Mono Just: Just..
```

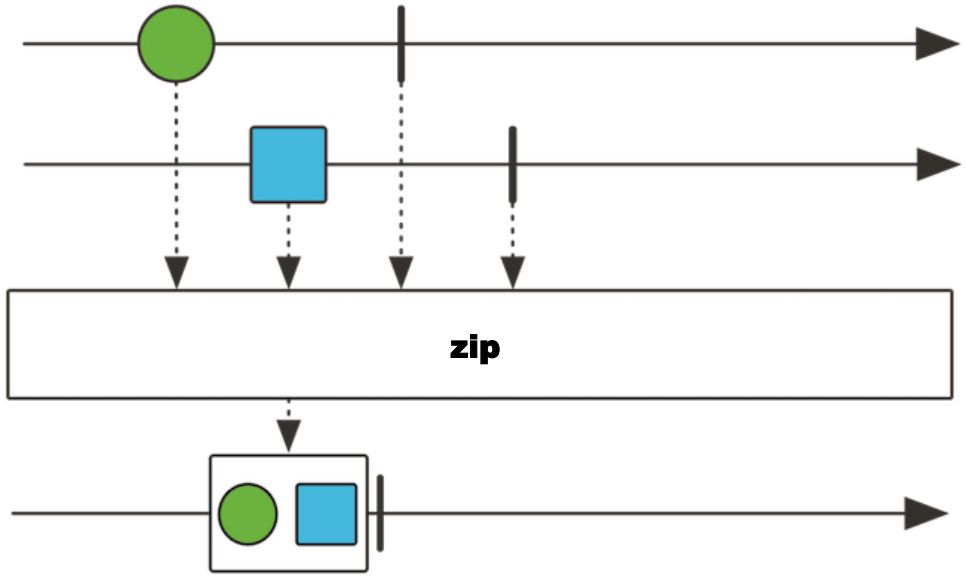
Mono

- Creating Mono via static methods:
  - never()
    - Mono<T> which never completes



Mono

- Creating Mono via static methods:
  - zip(Iteratable<Mono<T>> monos, Function<T,R> combiner)
  - zip(Function<T,R> combiner, Mono<T>… monos)
    - combines all Mono<T> results as Object[] using combiner function



Mono

- Example:
  - zip(...)

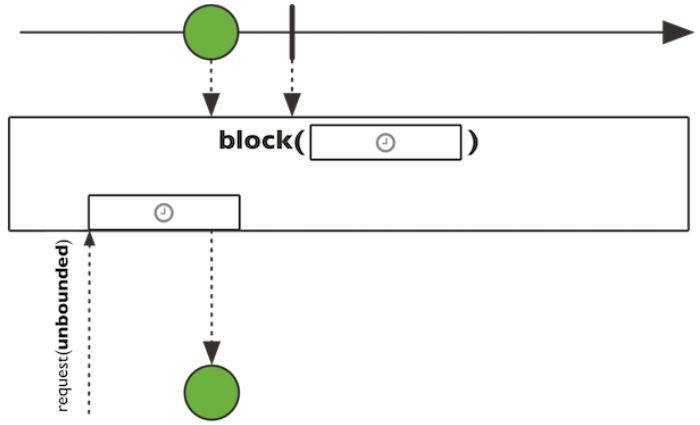
```
//reduces to total words length
public Mono<Integer> monoZip(String ...data){
     List<Mono<String>> monos=new ArrayList<>();
     for(int x=0;x<data.length;x++) {
          monos.add(Mono.just(data[x]));
     }
     return Mono.zip(monos,(results)->{
               int total=0;
               for(Object r:results) {
                    total+=((String)r).length();
               }
               return total;
          });
}
```

```
System.out.println("\nMono Zip: "+ex.monoZip("a","bb","ccc").block());
```

```
Mono Zip: 6
```

Mono

- Mono instance main methods:
  - as(Function<Mono<T>,R> transformer)
    - transforms Mono<T> into R
  - block()
  - block(Duration duration)
    - waits until next signal and returns T
  - blockOptional()
  - blockOptional(Duration duration)
    - waits until next signal or Mono completes empty, returns Optional<T>

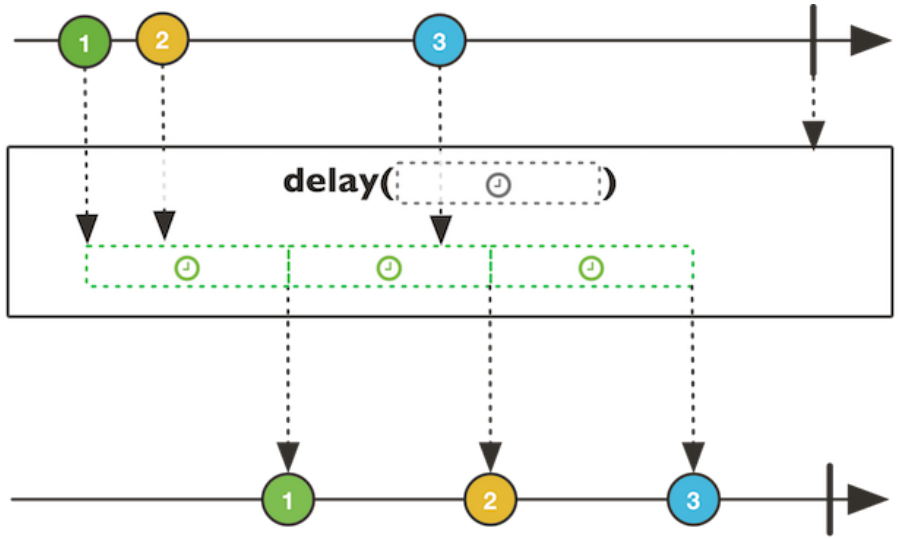


Mono

- Mono instance main methods:
  - cancelOn(Scheduler expiration)
    - sets subscriber to discard Mono<T> request on expiration
  - checkpoint()
    - activates assembly mono tracer
    - returns Mono<T> which will be the highest point up the stream or exception
    - should be used close to the end of the stream in order to reduce stack trace weight

Mono

- Mono instance main methods:
  - delayElement(Duration duration)
  - delayElement(Duration duration, Scheduler scheduler)
    - returns Mono<T> after specified duration
    - basically used for placing sleep() like actions on the stream



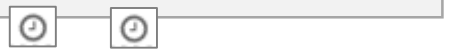
Mono

- Example:
  - delayElement(...)

```
public Mono<String> monoDelayElement(String data){
     return Mono.just("1").doOnNext(System.out::print).doOnNext(s->System.out.println(" --("+s+")--"));
}
```

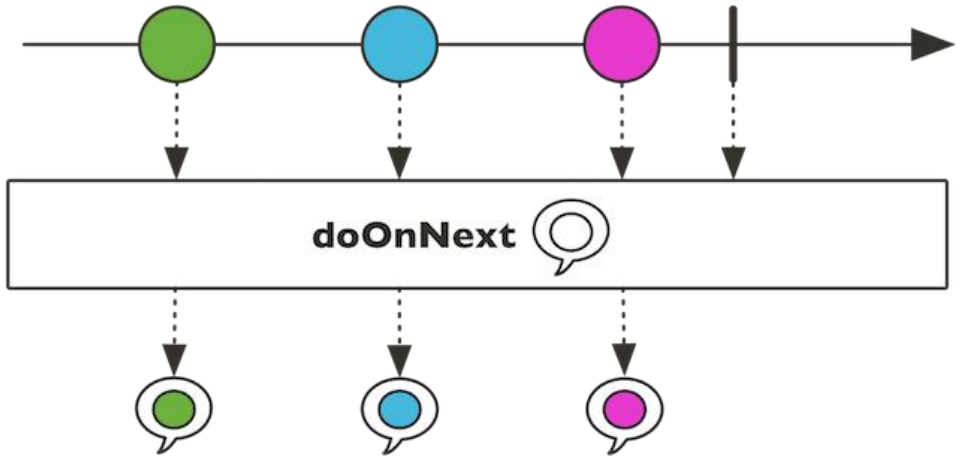
```
System.out.println("\nMono Delay Element: ");
ex.monoDelayElement().block();
```

```
Mono Deley Element:
Hi ! Hi ! Hi !
```



Mono

- Mono instance main methods:
  - doOnNext(Consumer<T> consumer)
  - doAfterSuccessOrError(BiConsumer<T, Throwable> consumer)
    - uses given consumer to process T
    - BiConsumers assigned values:
      - null & null for empty mono
      - T & null for normal mono outcome
      - null & exception on mono error



Mono

- Example:
  - doOnNext(...)

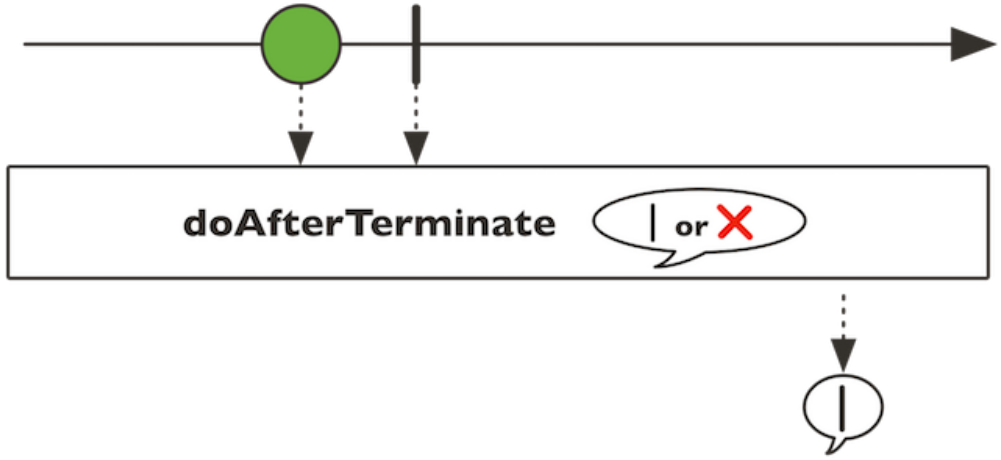
```
public Mono<String> monoDoOnNext(String data){
     return Mono.just("1").doOnNext(System.out::print).doOnNext(s->System.out.println(" --("+s+")--"));
}
```

```
System.out.println("\nMono DoOnNext: ");
ex.monoDoOnNext().block();
```

```
Mono DoOnNext:
              1 --(1)--
```

Mono

- Mono instance main methods:
  - doOnTerminate(Runnable task)
    - executes task after Mono<T> termination
  - doFinally(Consumer<SignalType> consumer)
    - Delegates to given consumer ‘completion type’ which might be:
      - SignalType.ON_COMPLETE
      - SignalType.ON_ERROR
      - SignalType.ON_CANCEL



Mono

- Example:
  - doOnTerminate(...)

```
public Mono<String> monoDoOnNext(String data){
     return Mono.just("Done ! ").doOnTerminate(()->System.out.println("On Terminate"));
}
```

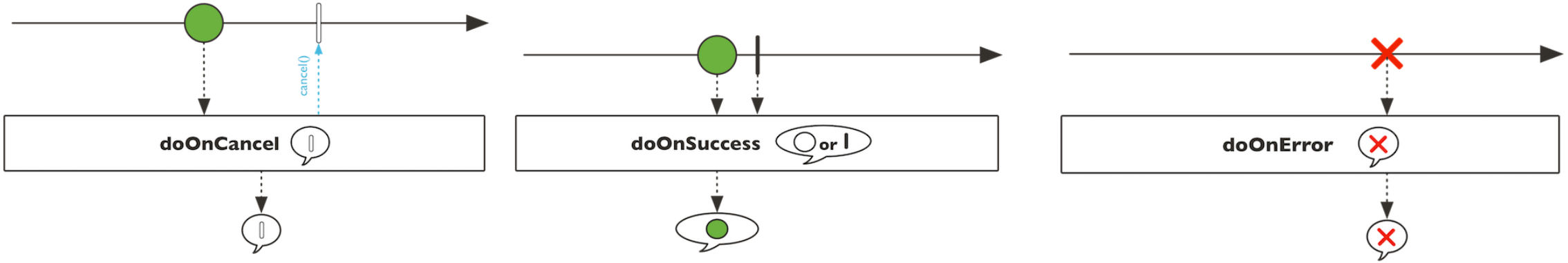
```
System.out.println("\nMono DoOnNext: ");
ex.monoDoOnTerminate().block();
```

```
Mono On Terminate:
On Terminate

Done !
```

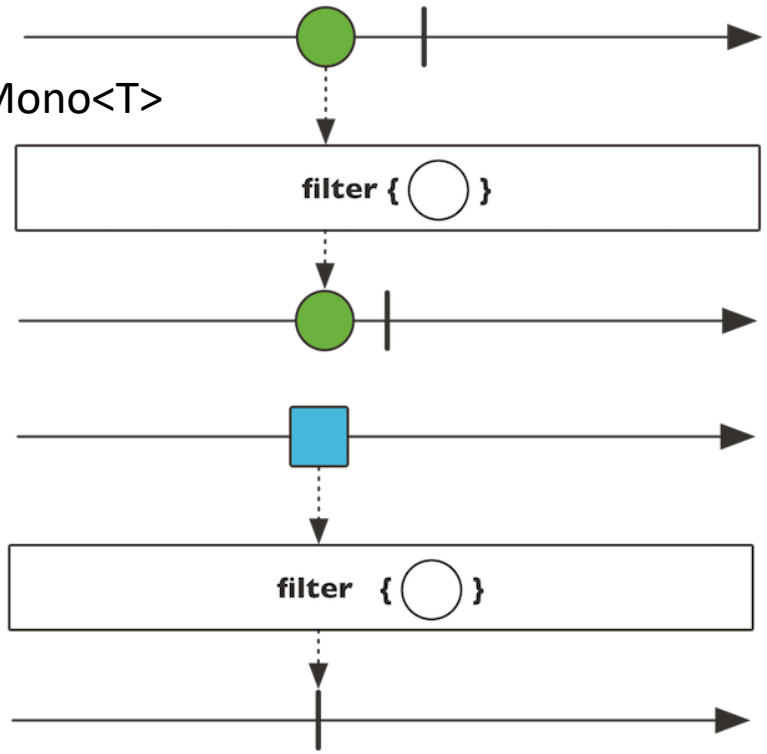
Mono

- Mono instance main methods:
  - doOnCancel(Runnable task)
    - executes given task only if & after Mono<T> cancellation
  - doOnSuccess(Consumer<T> consumer)
    - delegates T to given consumer only in case of success
  - doOnError(Consumer<Throwable> consumer)
  - doOnError(Class<E> exceptionType, Consumer<E> consumer)
    - delegates exception/specific-exception to given consumer only in case of success



Mono

- Mono instance main methods:
  - filter(Predicate<T> tester)
    - tests Mono<T> value if exists:
      - true - Mono<T> - if value passes the test (true) – replays Mono<T>
      - false or no-value – completes without any value



Mono

- Example:
  - filter(...)

```
public Mono<Integer> monoFilter(int value){
     return Mono.just(value).filter(i->i%2==0);
}
```

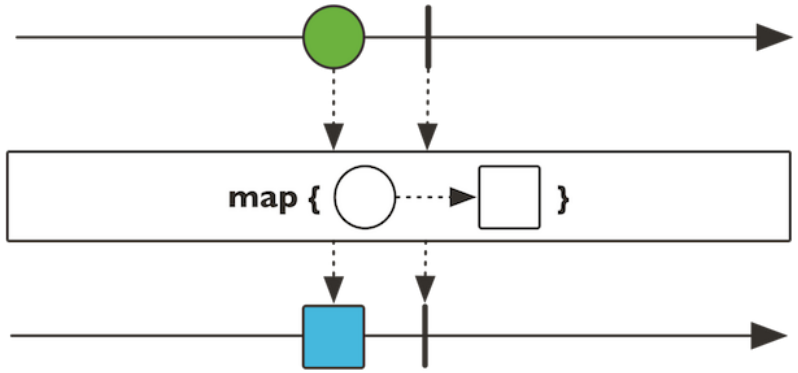
```
System.out.println("\nMono Filter(passes test): "+ex.monoFilter(20).block());
System.out.println("\nMono Filter(fails test): "+ex.monoFilter(13).block());
```

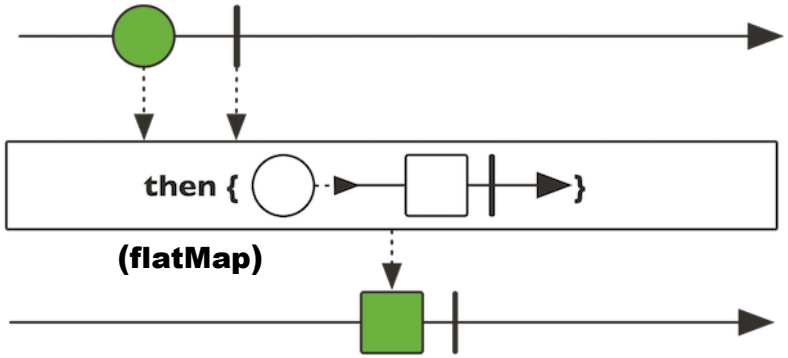
```
Mono Filter(passes test): 20

Mono Filter(fails test): null
```

Mono

- Mono instance main methods:
  - map(Function<T, Mono<R>> mapper)
    - synchronously creates Mono<R> from Mono<T> by applying resulted T to a given mapper
  - flatMap(Function<T, Mono<R>> mapper)
    - asynchronously creates Mono<R> from Mono<T> by applying resulted T to a given mapper





Mono

- Example:
  - flatMap(...)

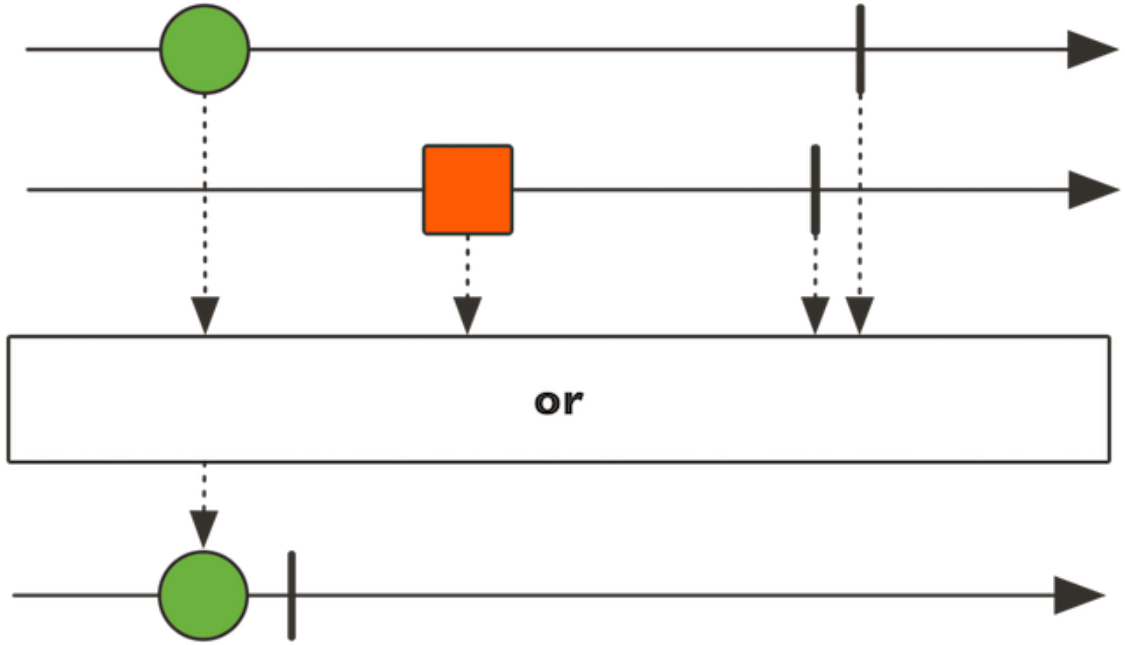
```
public Mono<Integer> monoFilter(int value){
    return Mono.just(value).flatMap(s->Mono.just(s.length()));
}
```

```
System.out.println("\nMono FlatMap: "+ex.monoFlatMap("Hello Reactive !").block());
```

```
Mono FlatMap: 16
```

Mono

- Mono instance main methods:
  - or(Mono<T> alternative)
    - returns the first completed Mono<T> - this or alternative



Mono

- Example:
  - or(...)

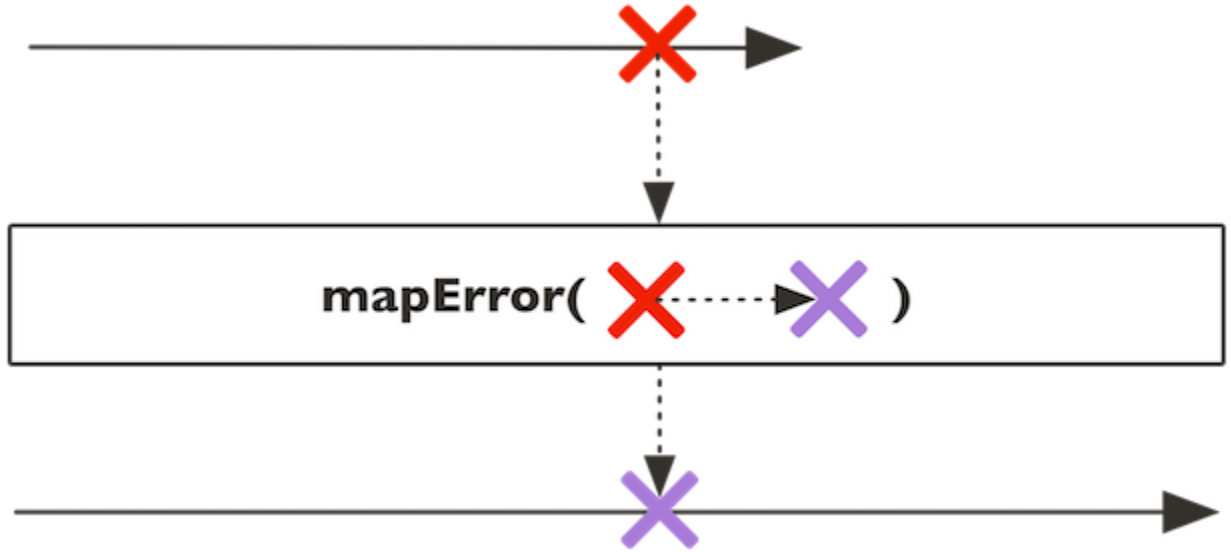
```
public Mono<String> monoOr(int delay1, int delay2){
    Mono<String> first=Mono.just("First").delayElement(Duration.ofSeconds(delay1));
    Mono<String> last=Mono.just("Second").delayElement(Duration.ofSeconds(delay2));
    return first.or(last);
}
```

```
System.out.println("\nMono Or: "+ex.monoOr(1,2).block());
```

```
Mono Or: First
```

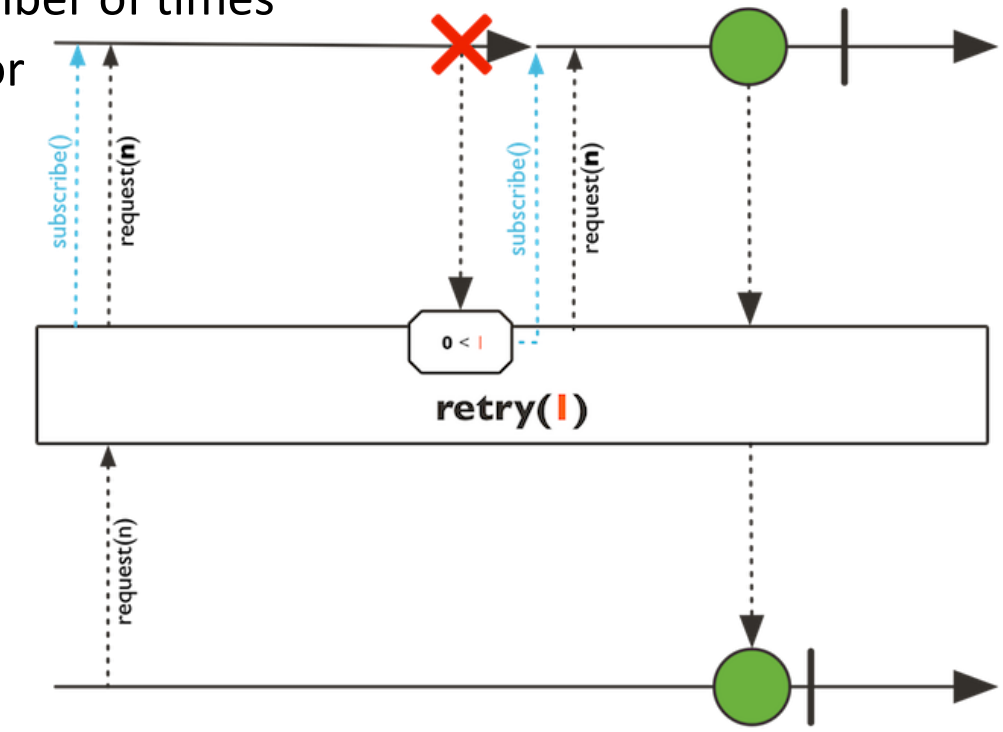
Mono

- Mono instance main methods:
  - onErrorMap(Function<T,T> mapper)
    - maps Throwable into other Throwable, returns Mono<T>



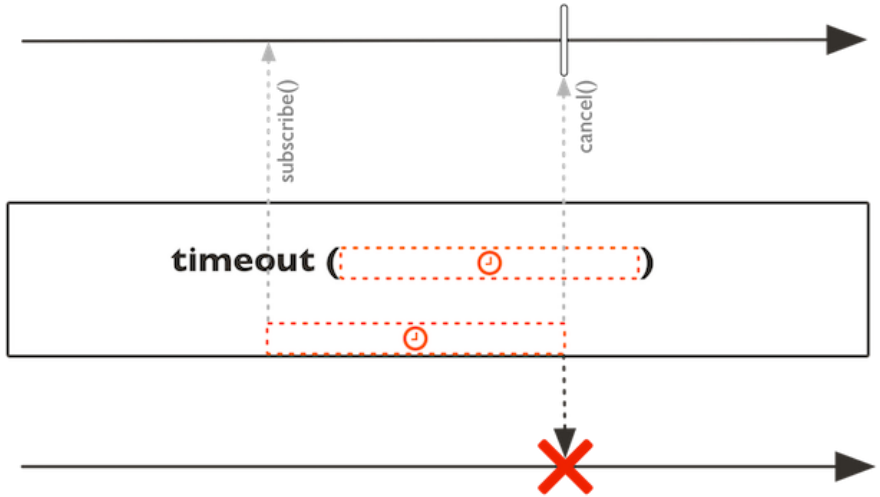
Mono

- Mono instance main methods:
  - retry(long numOfRetries)
    - re-subscribe to this Mono for fixed number of times
    - retries only while terminating with error



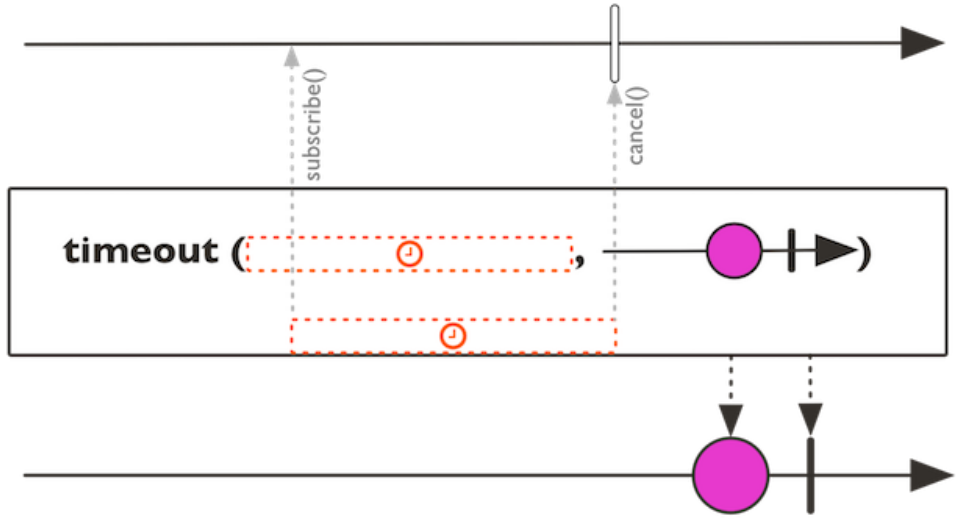
Mono

- Mono instance main methods:
  - take(Duration duration)
  - take(Duration duration, Scheduler scheduler)
    - gives Mono time to complete within specified timeframe
  - timeout(Duration duration)
  - timeout(Duration duration, Scheduler timer)
    - waits for completion
    - propagates TimeoutException when mono fails to complete within given timeframe



Mono

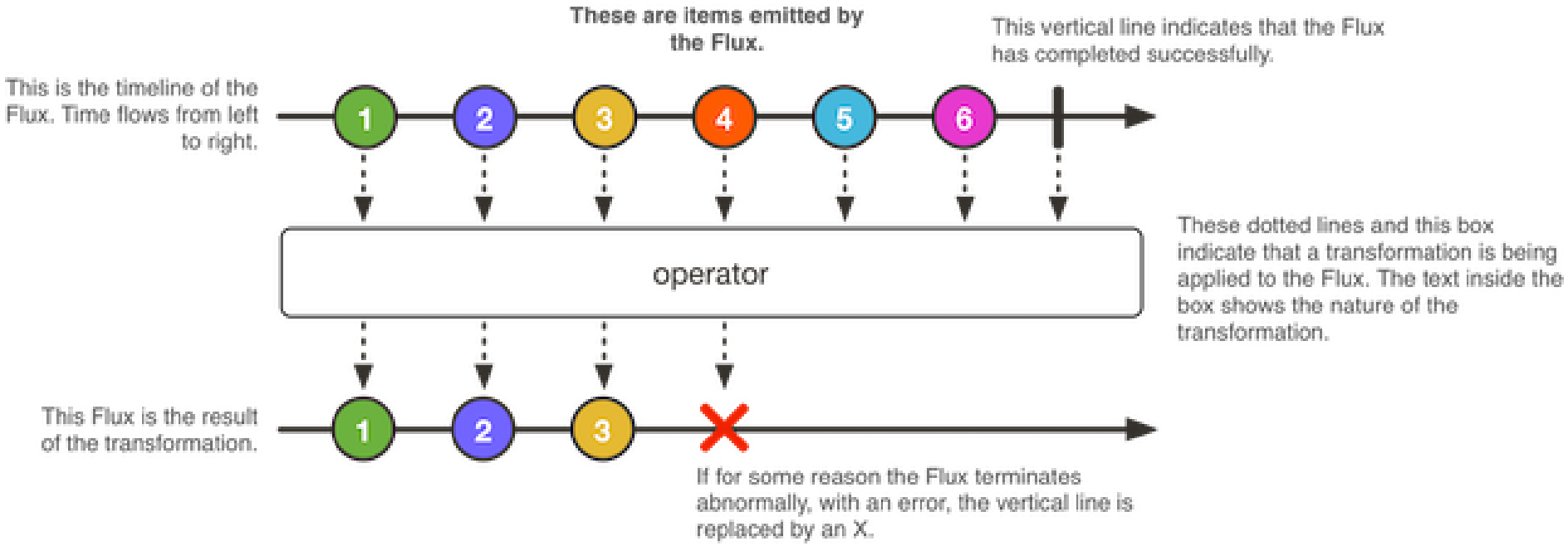
- Mono instance main methods:
  - timeout(Duration duration, Mono<T> fallback)
  - timeout(Duration duration, Mono<T> fallback, Scheduler timer)
    - waits for completion
    - fallbacks to givenMono<T> when mono fails to complete within given timeframe



Flux

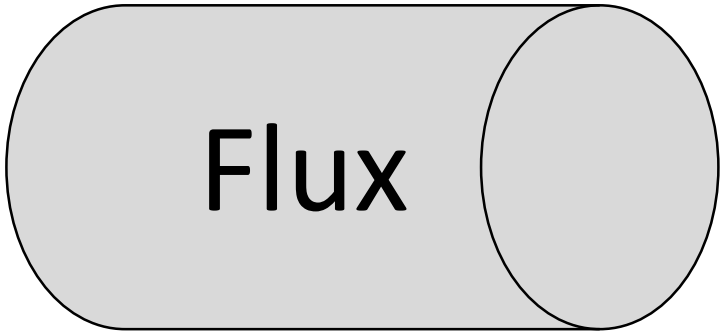
Flux

- For emitting:
  - 0-N elements
  - Error



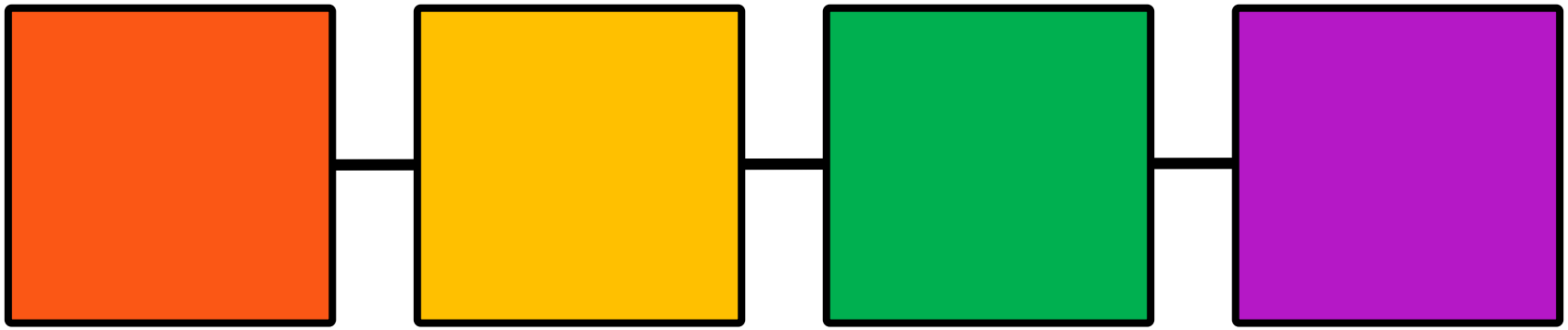
Flux

- Flux characteristics
  - Lazily executed (..are streams)
  - Immutable – every flux method factors another
  - Can be finite or infinite
  - Flux subscribers can
    - Decide when to start
    - Specify how much to take
    - Decide when to stop



Flux

- Creating Flux via static methods:
  - create(Consumer<FluxSink> emitter)
    - creates Flux<T> using Consumer<T>
  - fromArray(T[] array)
  - fromIterable(Iterable<T> collection)
  - fromStream(Stream<T> stream)



Flux

- Example:
  - create(...)

```
public Flux<Double> fluxCreate(){
      return Flux.create(sink->sink.next(Math.random()));
}
```

```
System.out.print("\nFlux Create: \n");
Flux<Double> f=ex.fluxCreate();
f.subscribe(System.out::println);
f.subscribe(System.out::println);
```

```
Flux Create:
0.1018257230717331
0.05922774911639461
```

Flux

- Example:
  - from(...)

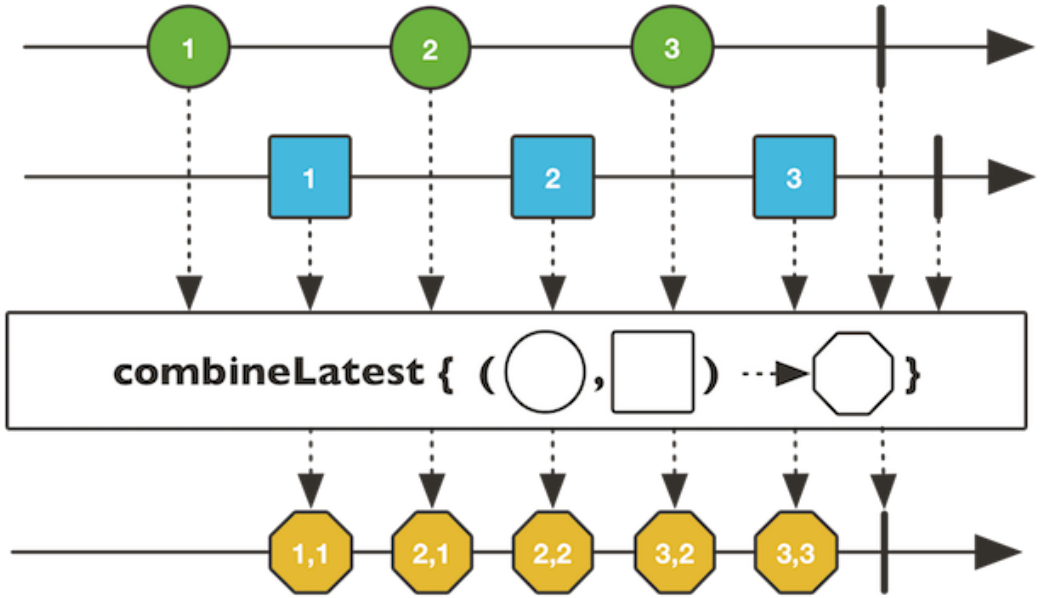
```
public Flux<String> fluxFrom(){
      return Flux.fromStream(Stream.of("aaa","bbb","ccc"));
}
```

```
System.out.print("\nFlux From: ");
ex.fluxFrom().subscribe(System.out::print);
```

```
Flux From: aaabbbccc
```

Flux

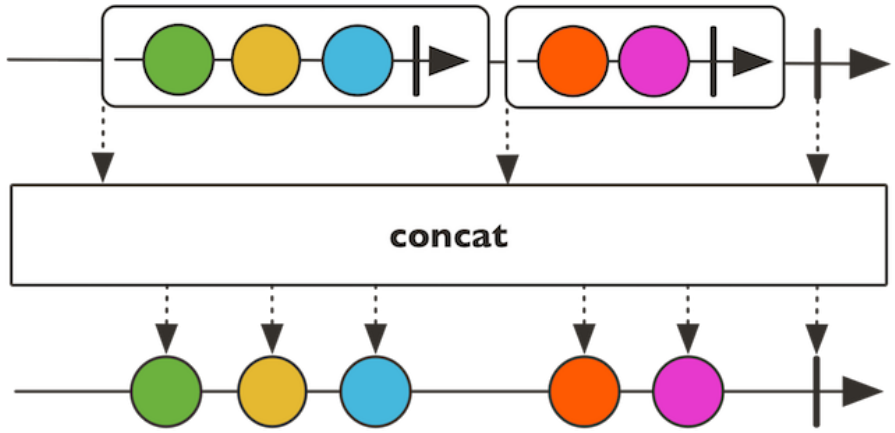
- Creating Flux via static methods:
  - combineLatest(Function (Object[] lastResults, V combiner, Publisher<T>…sources)
  - combineLatest(Iteratable<T> sources, Function (Object[] lastResults, V combiner)
    - all latest results (T sources) are combined into Flux<V>



Flux

- Creating Flux via static methods:
  - concat(Publisher<T> sources)
  - concatWith(Iteratable<Publisher<T>> sources)
    - appends all value emitted by each publisher into one Flux<T>
  - concatWithValues(T… values)
    - fuses all value with current Flux<T> into new one

    Note: Doesn’t eagerly subscribe any elements



Flux

- Example:
  - concat(...)

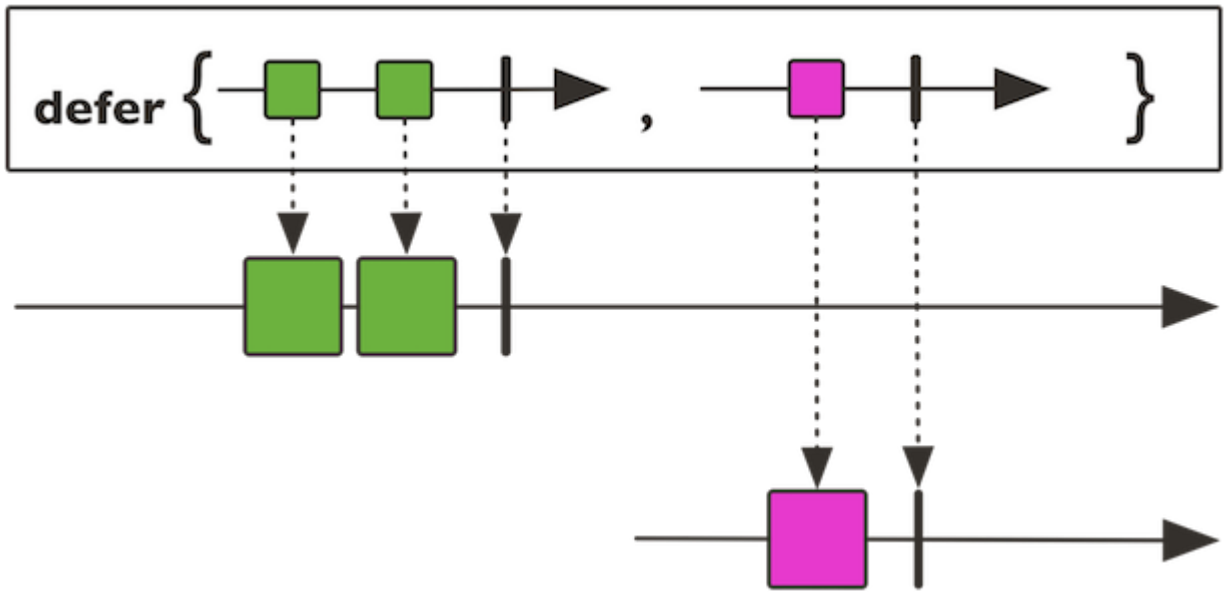
```
public Flux<String> fluxConcat(String...values){
      return fluxFrom().concatWithValues(values);
}
```

```
System.out.print("\n\nFlux Concat: ");
ex.fluxConcat("1","2","3").subscribe(System.out::print);
```

```
Flux Concat: aaabbbccc123
```

Flux

- Creating Flux via static methods:
  - defer(Supplier<Publisher<T>> publisher)
    - creates new Flux<T> out of given Flux<T>



Flux

- Example:
  - defer(...)

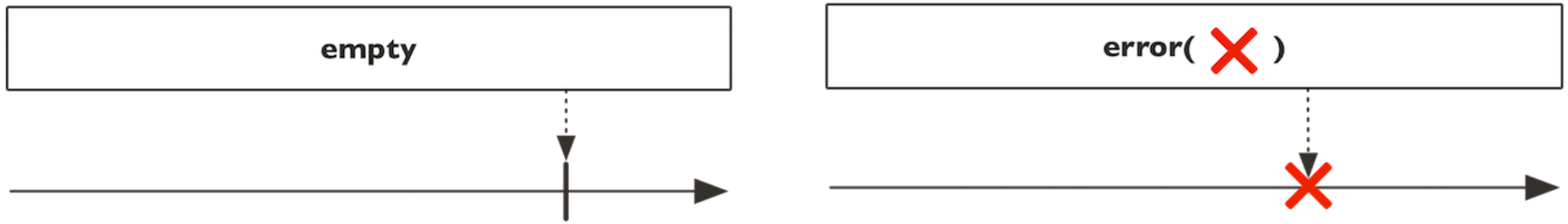
```
public Flux<Integer> fluxDefer(){
   return Flux.defer(()->Flux.fromStream(IntStream.range(1,6).mapToObj(i->new Integer(i))));
}
```

```
System.out.print("\n\nFlux Defer: ");
ex.fluxDefer().subscribe(System.out::print);
```

```
Flux Defer: 12345
```

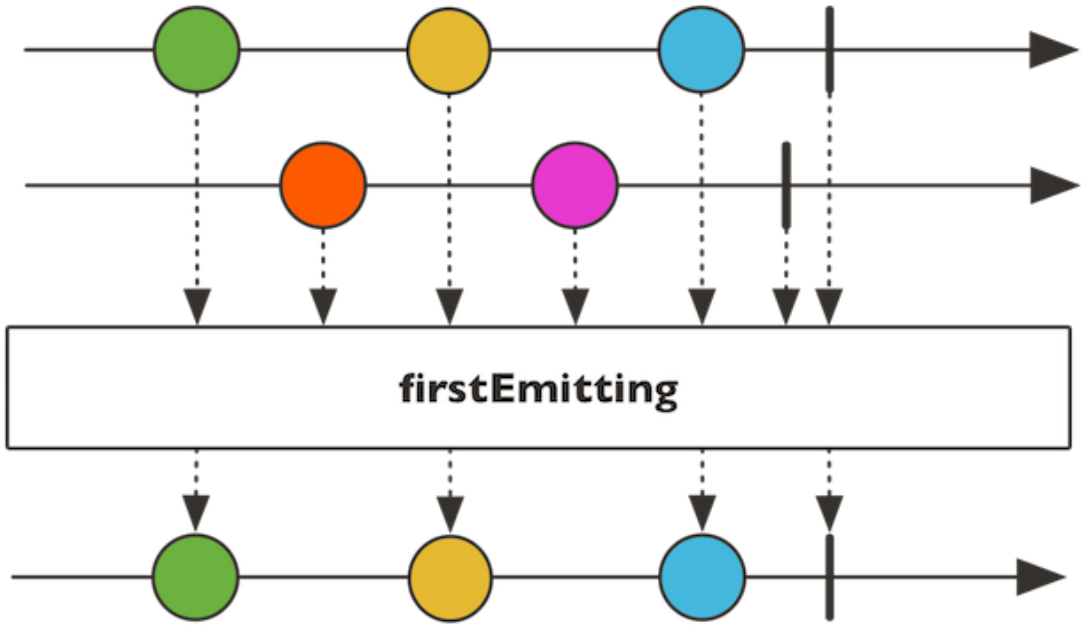
Flux

- Creating Flux via static methods:
  - empty()
    - creates new Flux<T> which complete without emitting any item
  - error(Throwable error)
    - creates new Flux<T> which complete with given error



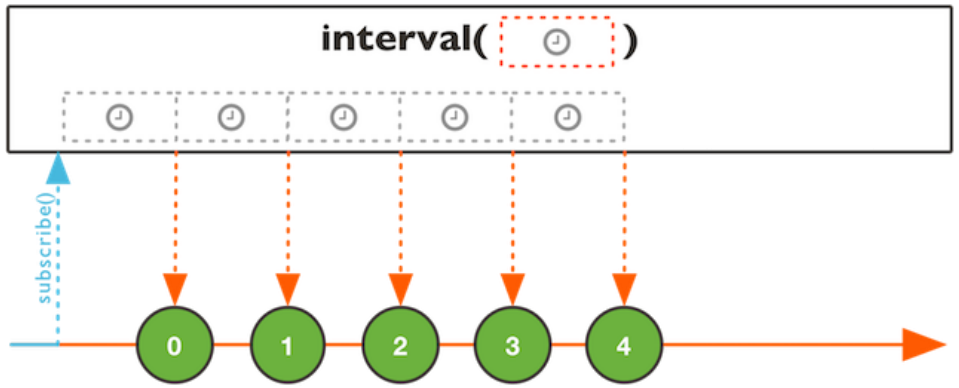
Flux

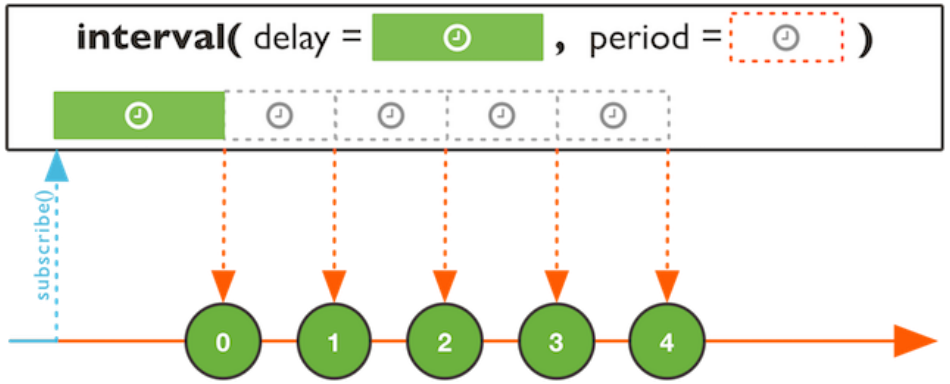
- Creating Flux via static methods:
  - first(Publisher<T>…sources)
    - returns Flux<T> from the first source which signals onNext/onError/onComplete
    - basically performs a Flux sources race



Flux

- Creating Flux via static methods:
  - interval(Duration period)
  - interval(Duration delay, Duration period)
  - interval(Duration period, Scheduler timer)
    - Returns Flux<Long>
    - Increments values every ‘period’





Flux

- Example:
  - interval(...)

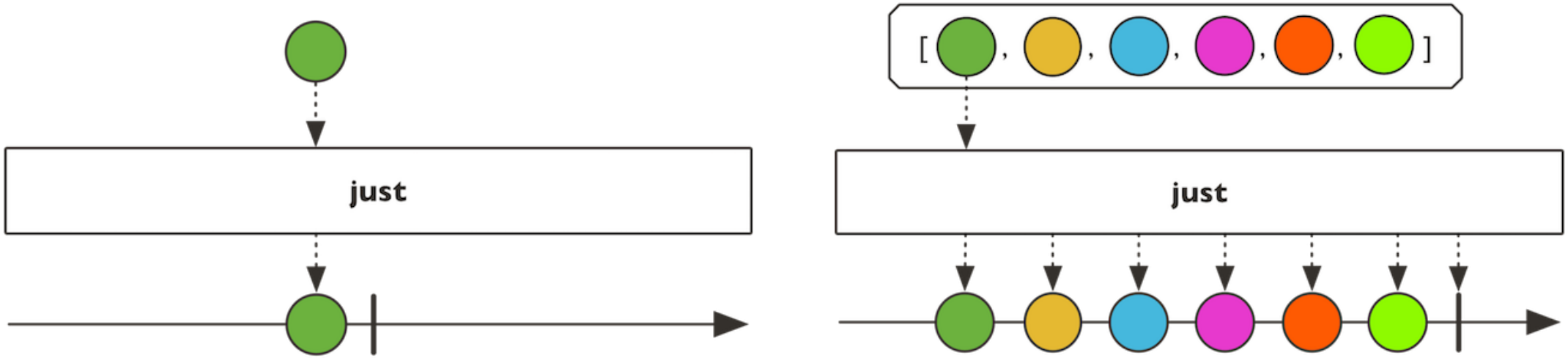
```
public Flux<Long> fluxInterval(int millis, int count){
   return Flux.interval(Duration.ofMillis(millis)).take(count);
}
```

```
System.out.print("\n\nFlux Interval: ");
ex.fluxInterval(500,10).subscribe(System.out::print);
```

```
Flux Interval: 012
```

Flux

- Creating Flux via static methods:
  - just(T data)
    - Creates Flux<T> which emits a single value
  - just(T… data)
    - Creates a Flux<T> with multiple values



Flux

- Creating Flux via static methods:
  - just(T… data) important notification:

As expected,

- Flux.just(T) creates Flux<T>
- Flux.just(T1, T2, T3, …) creates Flux<T>

BUT – assigning pre-defined array/varargs in one of the following ways:

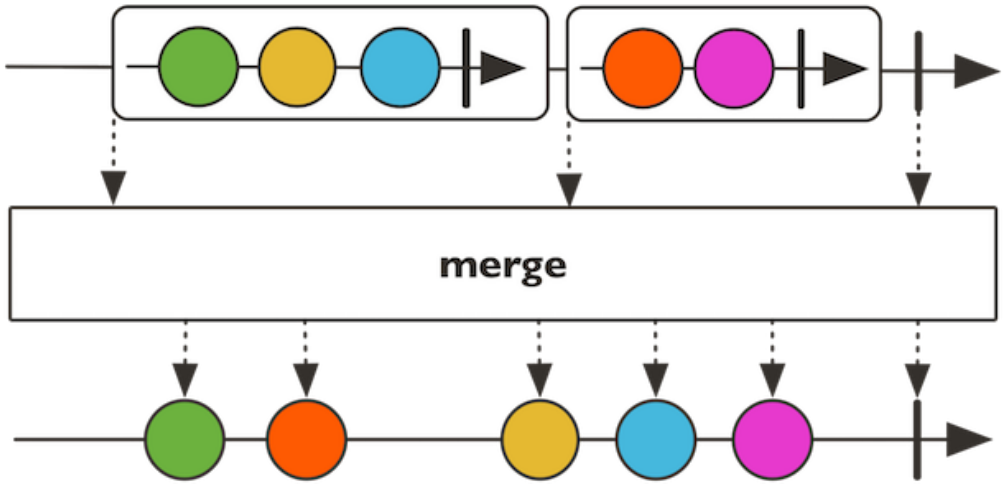
- T[] **tArr** = {T1, T2, T3} or
- method(T…tArr) or
- method(T[] tArr)

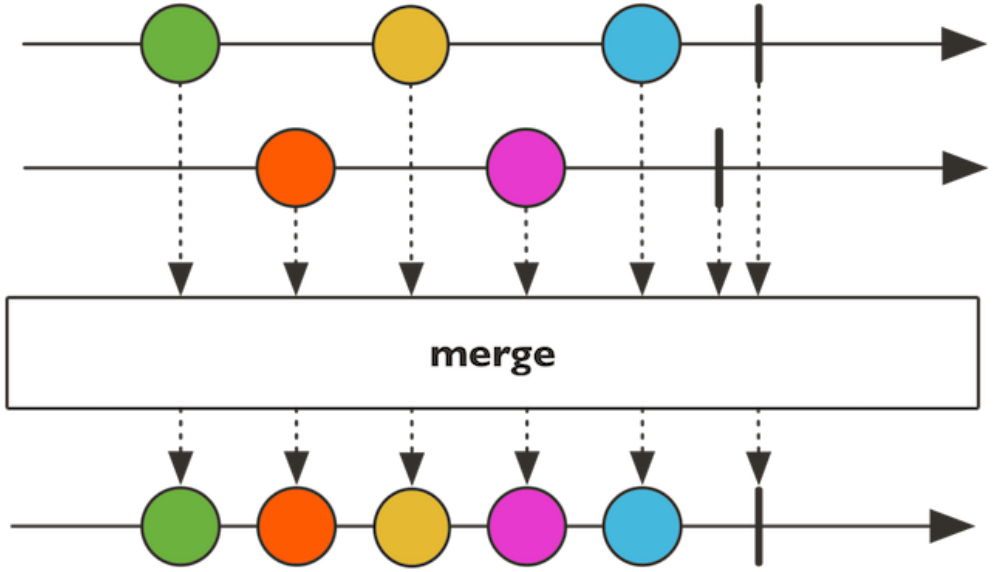
NOTE THAT: Flux.just(**tArr**) creates **Flux<T[]>**

  - In order to crease Flux<T> from a given array use **Flux.fromArray()** instead

Flux

- Creating Flux via static methods:
  - merge(Publisher<T> toMerge)
  - merge(Iterable<Publisher<T>> toMerge)
    - merges publisher(s) into Flux<T>
    - unlike concat() – eagerly subscribes elements
    - Fluxes should be finite





Flux

- Example:
  - merge(...)

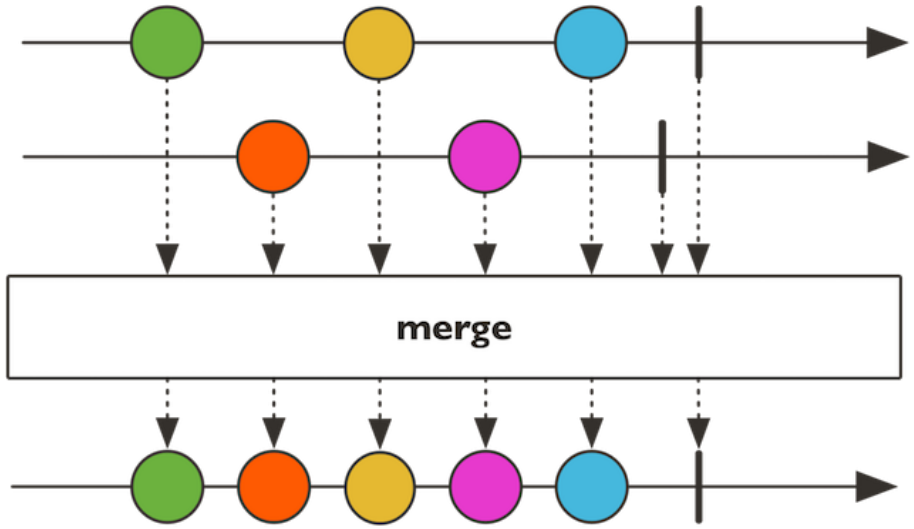
```
public Flux<Object> fluxMerge(){
   return Flux.merge(fluxInterval(100, 10),fluxFrom().delayElements(Duration.ofMillis(100)));
}
```

```
System.out.print("\n\nFlux Merge: ");
ex.fluxMerge().subscribe(System.out::print);
```

```
Flux Merge: 0aaa1bbb2ccc3445678596789
```

Flux

- Creating Flux via static methods:
  - mergeOrdered(Publisher<T>… toMerge)
  - mergeOrdered(Comparator<T>, Publisher<T>… toMerge)
    - merges publisher(s) into Flux<T>
    - peeks the smallest values available on the stream first
    - unlike concat() – eagerly subscribes elements



Flux

- Example:
  - mergeOrdered(...)

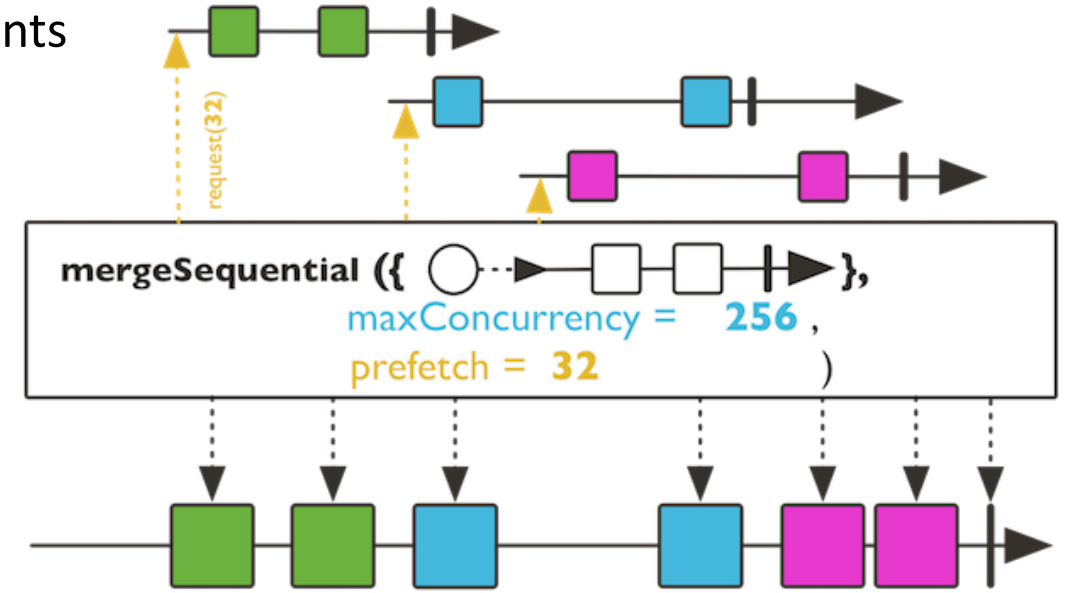
```
public Flux<Integer> fluxMergeOrdered(){
    Integer [] random1=randomizeArray();
    Integer [] random2=randomizeArray();
    return Flux.mergeOrdered(Flux.just(random1).delayElements(Duration.ofMillis(200)),
                             Flux.just(random2).delayElements(Duration.ofMillis(200)));
}
```

```
System.out.print("\n\nFlux Merge Ordered: ");
ex.fluxMergeOrdered().subscribe(System.out::print);
```

```
Flux Merge Ordered: 406188446603996277613051516309216383001 1
```

Flux

- Creating Flux via static methods:
  - mergeSequential(Publisher<T>… toMerge)
    - merges publisher(s) into Flux<T>
    - emits sequentially from each Publisher according to its registration order
    - each publisher data is appended to the stream after previous publisher completes
    - unlike concat() – eagerly subscribes elements
    - Unlike merge() – doesn't mix elements



Flux

- Example:
  - mergeSequental(...)

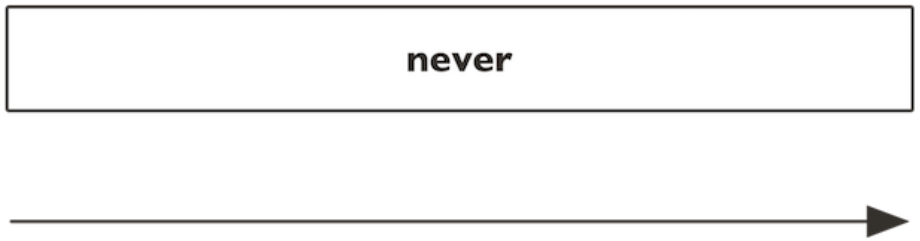
```
public Flux<Object> fluxMergeSequential(){
    return Flux.mergeSequential(fluxInterval(100, 10),fluxFrom(),fluxDefer());
}
```

```
System.out.print("\n\nFlux Interval: ");
ex.fluxMergeSequential(500,10).subscribe(System.out::print);
```

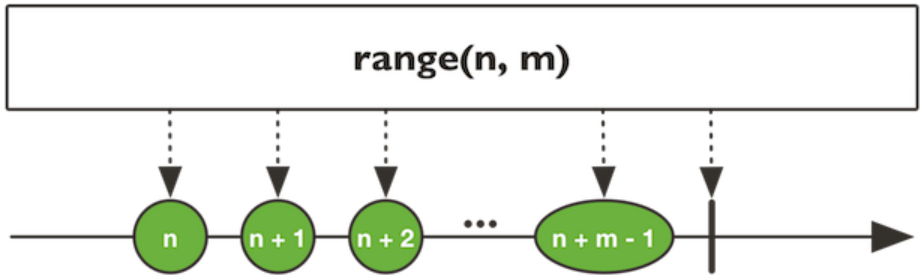
```
Flux Merge Sequential: 0123456789aaabbbccc12345
```

Flux

- Creating Flux via static methods:
  - never()
    - never ending flux
    - signals nothing



  - range(int start, int count)
    - generates Flux<Integer> with ‘count’ element starting from ‘start’ value



Flux

- Example:
  - range(...)

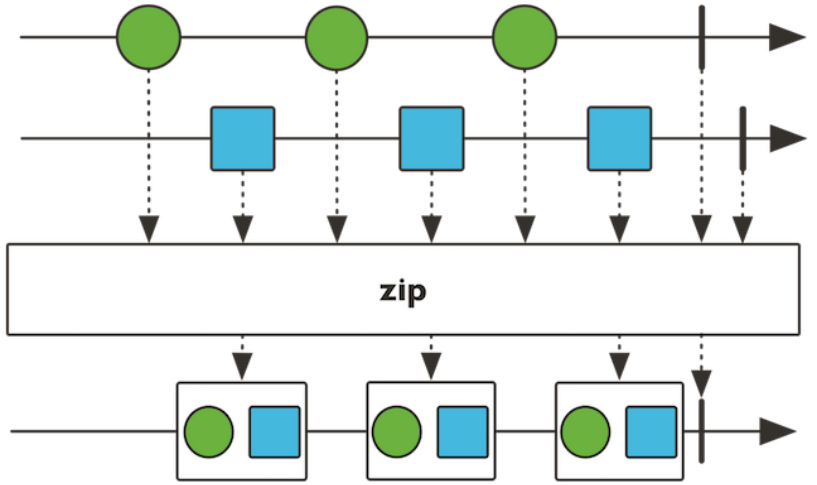
```
public Flux<Integer> fluxRange(){
    return Flux.range(0,10);
}
```

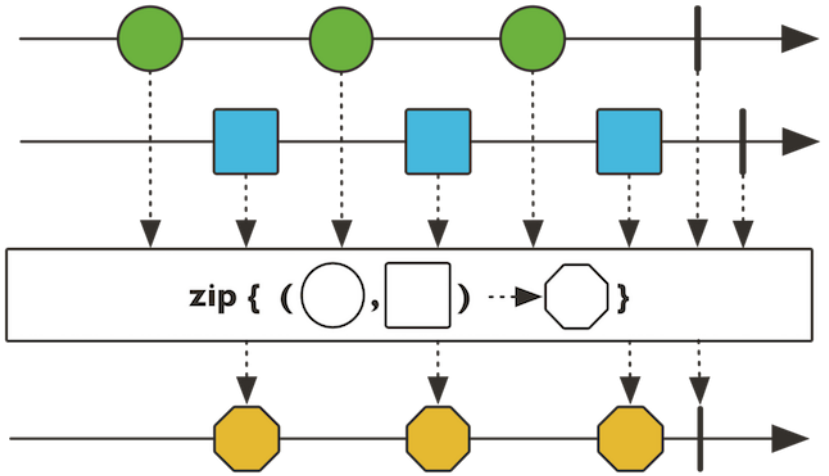
```
System.out.print("\n\nFlux Range: ");
ex.fluxRange().subscribe(System.out::print);
```

```
Flux Range: 0123456789
```

Flux

- Creating Flux via static methods:
  - zip(Publisher<T> p1, Publisher<E> p2)
    - Fuses p1 & p2 into Flux<Tuple2<T,E>>
    - Overloaded for Tubple2-Tuple6
  - zip(Function<Object[],O>, Publisher<T>…sources)
    - Fuses Publishers<T> with combiner function into Flux<O>
    - Object[] is a set of values subscribed, coordinately, from all sources





Flux

- Example:
  - zip(...)

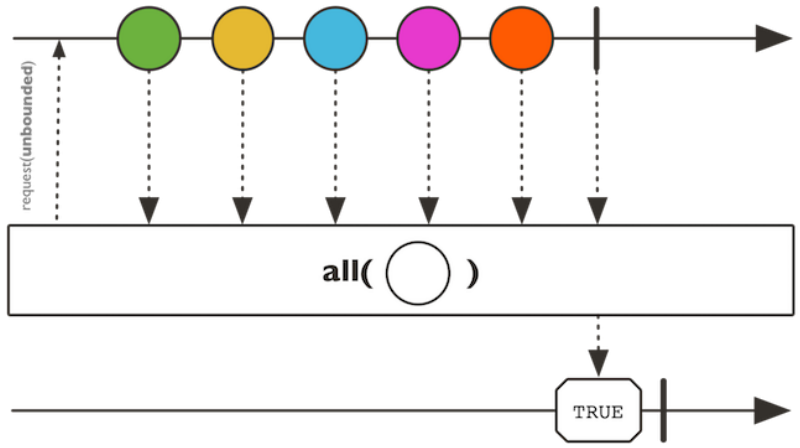
```
public Flux<String> fluxZip(){
return  Flux.zip((values)->{
                              String result="";
                              for(Object o:values) {
                                 result+=" "+o.toString();
                              }
                              return result;
                              },Flux.range(1,3),fluxFrom());
}
```

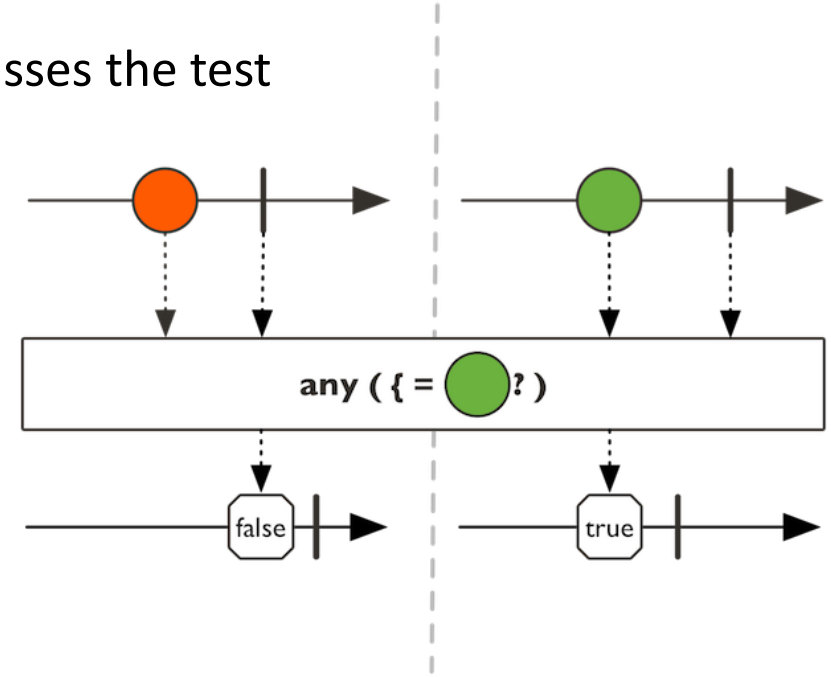
```
System.out.print("\n\nFlux Zip: \n");
ex.fluxZip().subscribe(System.out::println);
```

```
Flux Zip:
 1 aaa
 2 bbb
 3 ccc
```

Flux

- Flux instance main methods:
  - all(Predicate<T> test)
  - any Predicate<T> test)
    - results with Mono<Boolean>
    - true – if all/any ot the items in the stream passes the test





Flux

- Flux instance main methods:
  - as(Function<Flux<T>, P> transformer)
    - results with P calculated from Flux<T>
  - blockFirst()
  - blockFirst(Duration timeout)
  - blockLast()
  - blockLast(Duration timeout)
    - blocks until signaling on first/last value
    - returns that value as T

Flux

- Example:
  - as(...)

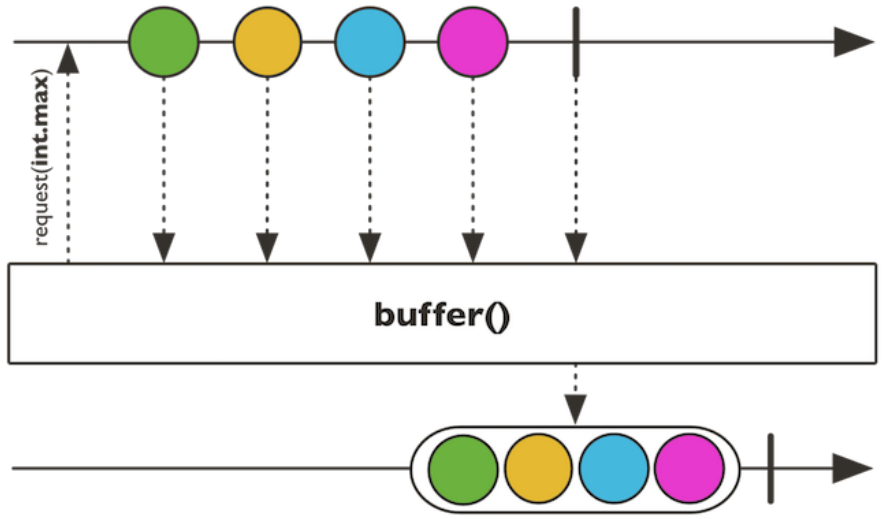
```
public Integer fluxAs(Integer...values){
    AtomicInteger i=new AtomicInteger(0);
    Flux.fromArray(values).as(flux->{
                                    flux.doOnNext(v->i.addAndGet(v)).subscribe();
                                    return 0;
                                });
    return i.get();
}
```

```
System.out.print("\n\nFlux As: "+ ex.fluxAs(1,2,3));
```

```
Flux As: 6
```

Flux

- Flux instance main methods:
  - buffer(List<T>)
    - collects items in given List
    - returns Flux<List<T>> when stream completes



Flux

- Example:
  - buffer()

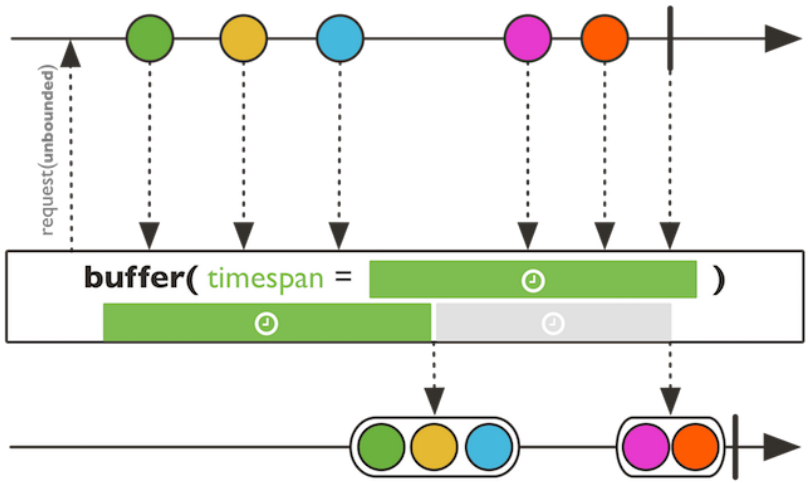
```
public Flux<List<Integer>> fluxBuffer(){
   return Flux.range(1,9).buffer();
}
```

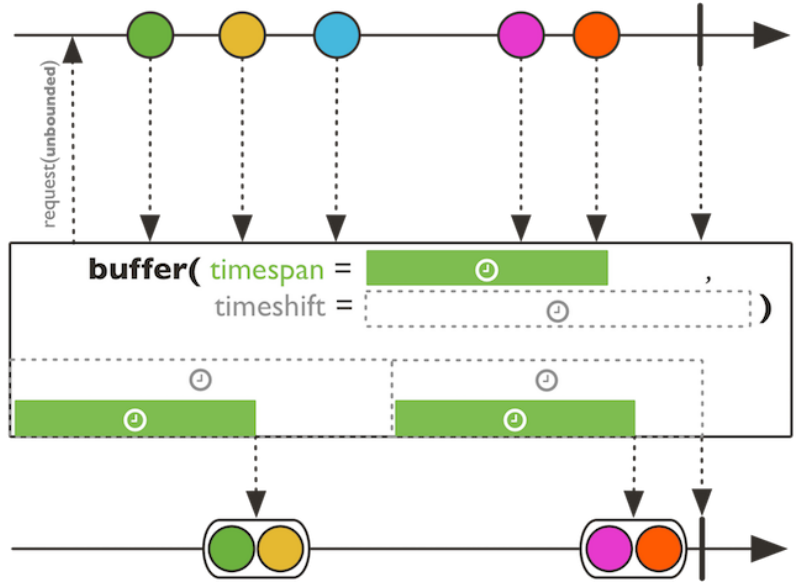
```
System.out.print("\n\nFlux Buffer: \n");
ex.fluxBuffer().subscribe(System.out::println);
```

```
Flux Buffer:
[1, 2, 3, 4, 5, 6, 7, 8, 9]
```

Flux

- Flux instance main methods:
  - buffer(Duration timespan)
    - collects items for given timespan
  - buffer(Duration timespan, Duration timeshift)
    - collects items for given timespan each time-shift

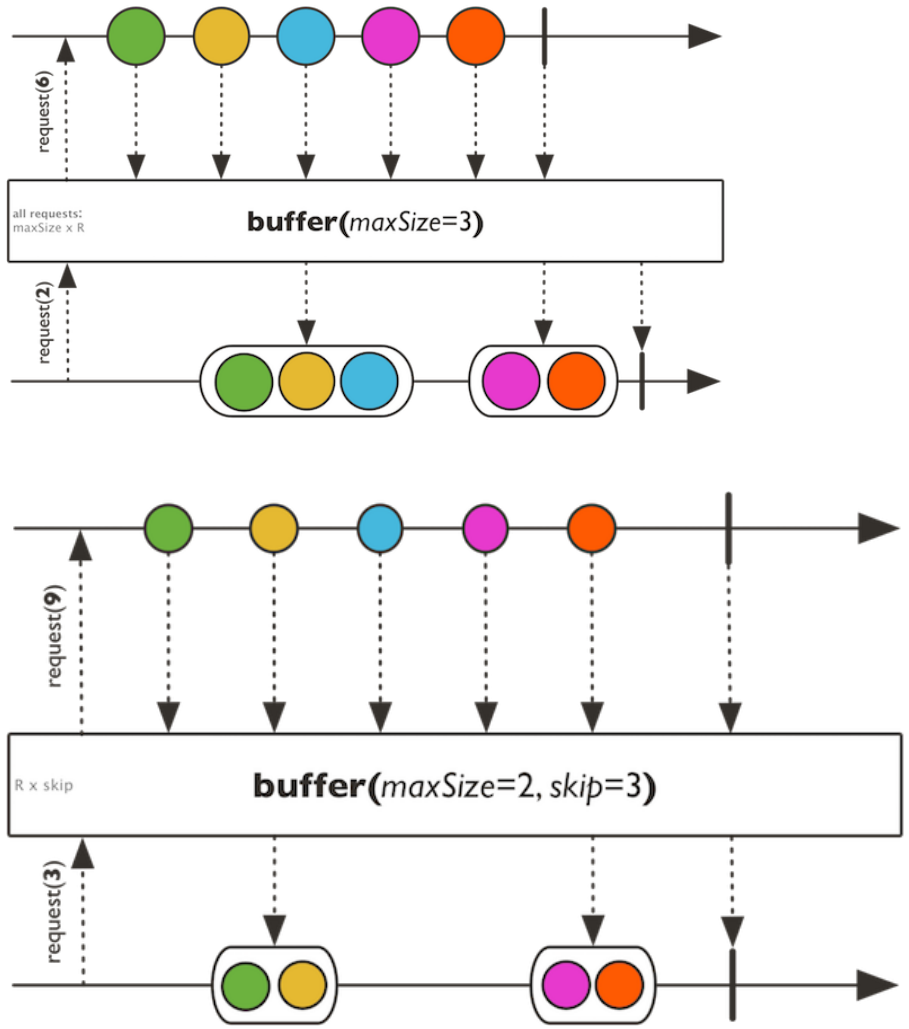




- returns Flux<List<T>>
- List<T> is signaled on expiration or when stream completes

Flux

- Flux instance main methods:
  - buffer(int maxSize)
  - buffer(int maxSize, int skip)
    - returns multiple Flux<List<T>> when ‘maxSize’ items collected or when stream completes
    - ‘skip’ specifies how many items to count before starting a new buffer



Flux

- Example:
  - buffer(…)

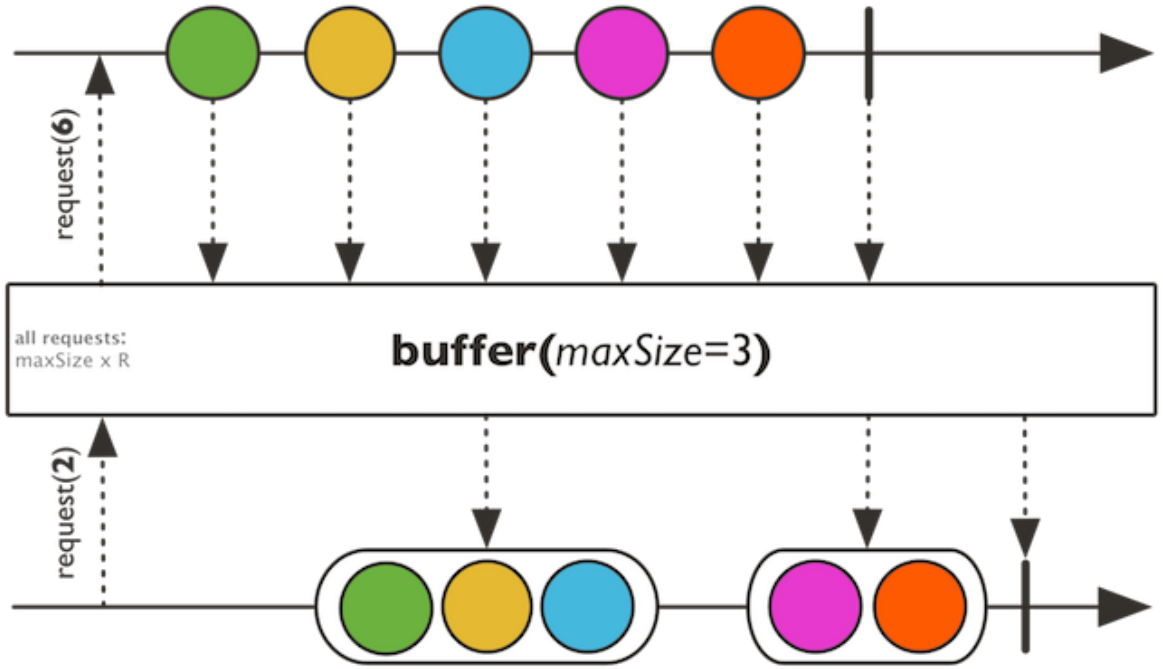
```
public Flux<List<Integer>> fluxBufferMaxSize(){
   return Flux.range(1,14).buffer(5);
}
```

```
System.out.print("\nFlux Buffer Max Size: \n");
ex.fluxBufferMaxSize().subscribe(System.out::print);
```

```
Flux Buffer Max Size:
[1, 2, 3, 4, 5][6, 7, 8, 9, 10][11, 12, 13, 14]
```

Flux

- Flux instance main methods:
  - bufferUntil(Predicate<T> test)
    - returns multiple Flux<List<T>>
    - each Flux is returned when item passes given test or when stream completes



Flux

- Example:
  - bufferUntil(…)

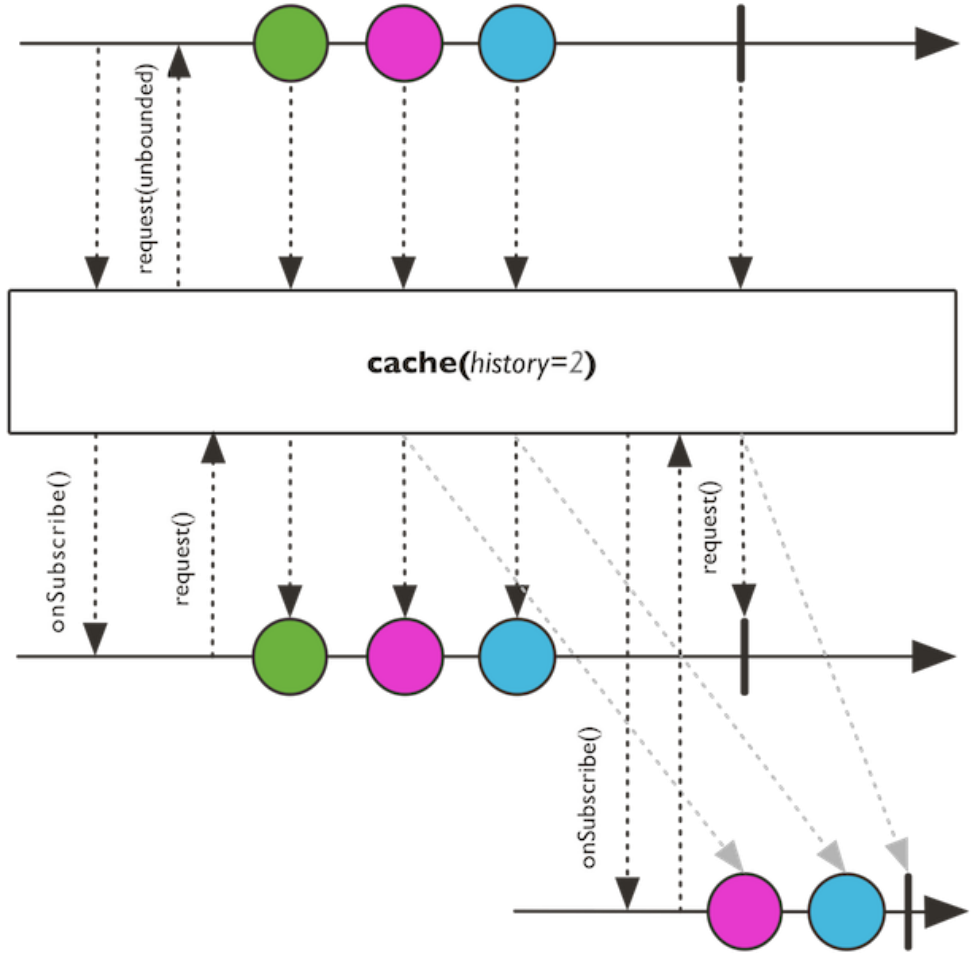
```
public Flux<List<Integer>> fluxBufferUntil(){
    return Flux.fromArray(randomizeArray()).bufferUntil(n->n==1||n==9);
}
```

```
System.out.print("\n\nFlux Buffer Until: \n");
Flux<List<Integer>> fl=ex.fluxBufferUntil();
fl.subscribe(System.out::print);
```

```
Flux Buffer Until:
[0, 2, 5, 1][9][8, 3, 2, 4, 5, 4, 9][8, 6, 6, 2, 6, 8, 6, 1]
```

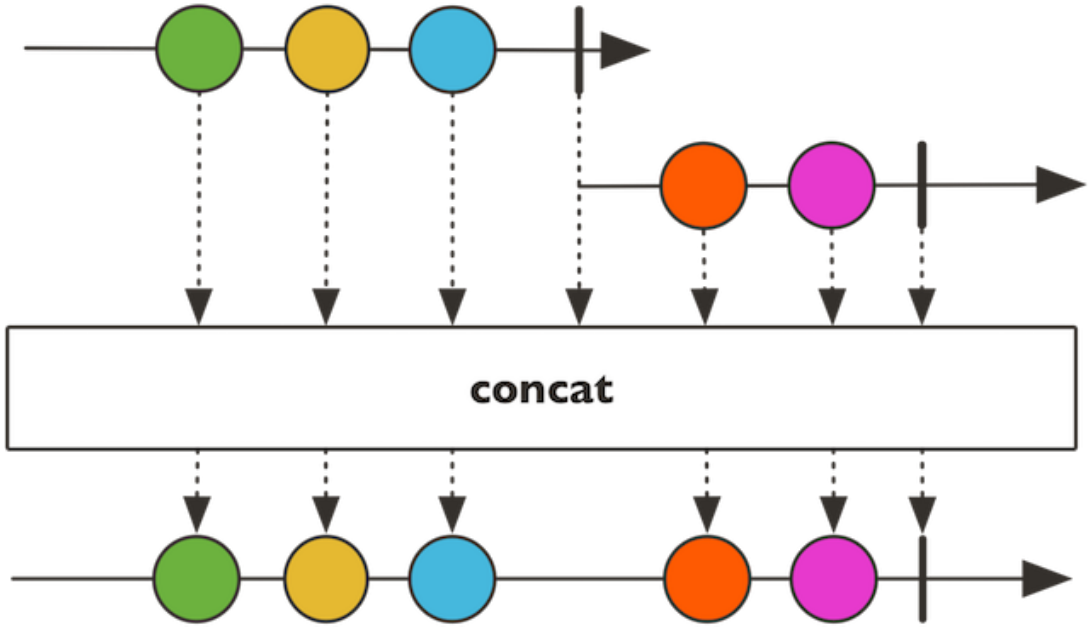
Flux

- Flux instance main methods:
  - cache(int history)
    - returns Flux<T> which caches ‘history’ number of items from origin Flux
    - latest history can be re-subscribed from resulted Flux



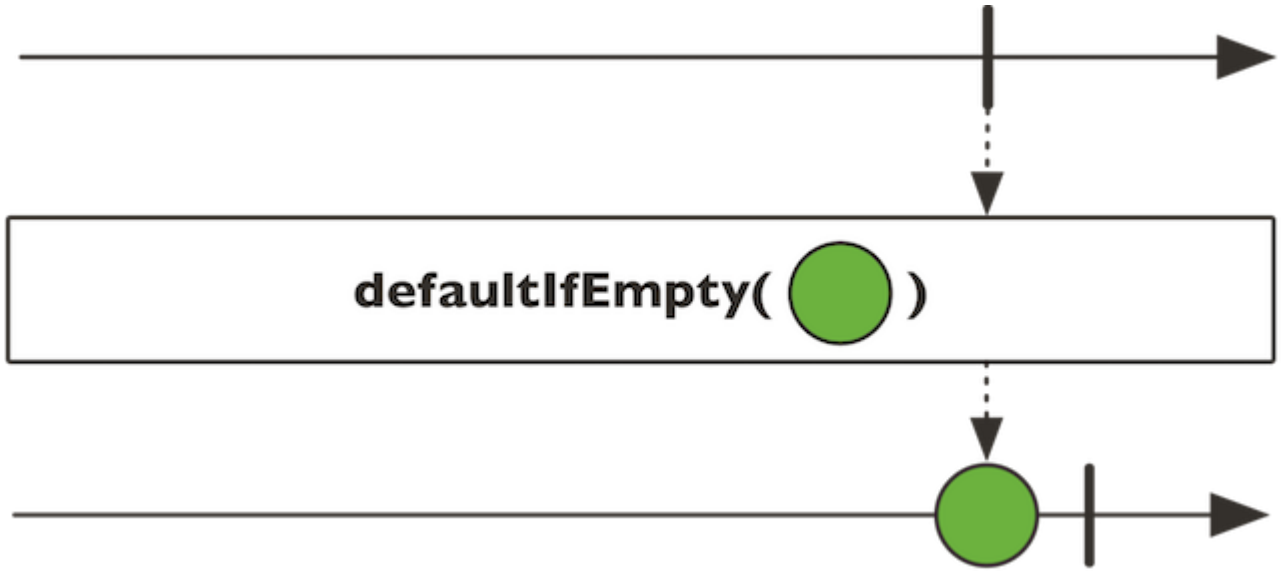
Flux

- Flux instance main methods:
  - concatWith(Publisher<T> source)
    - appends source to this Flux (after origin completes)
    - returns Flux<T>



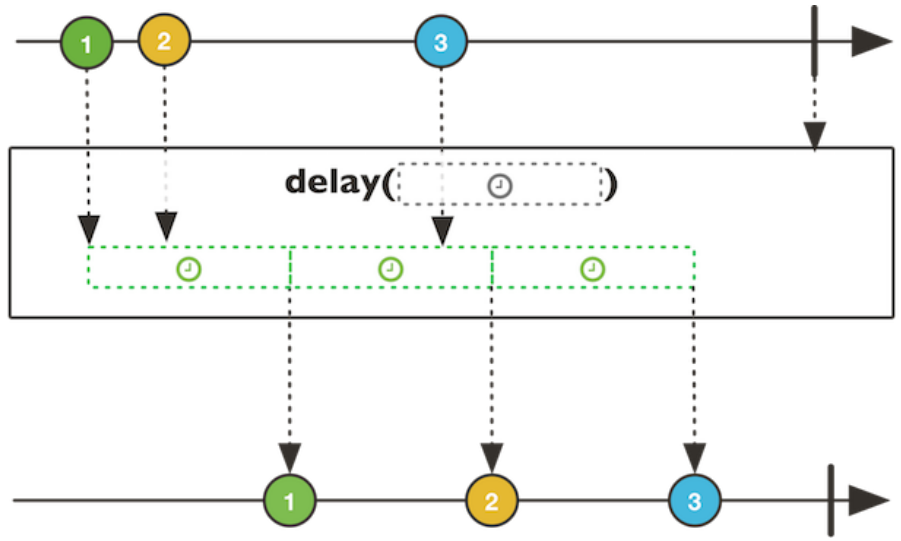
Flux

- Flux instance main methods:
  - defaultIfEmpty(T default)
    - returns T if Flux is empty



Flux

- Flux instance main methods:
  - delayElements(Duration delay)
  - delayElements(Duration delay, Scheduler timer)
    - Delays items subscription according to given delay



Flux

- Example:
  - delayElements(…)

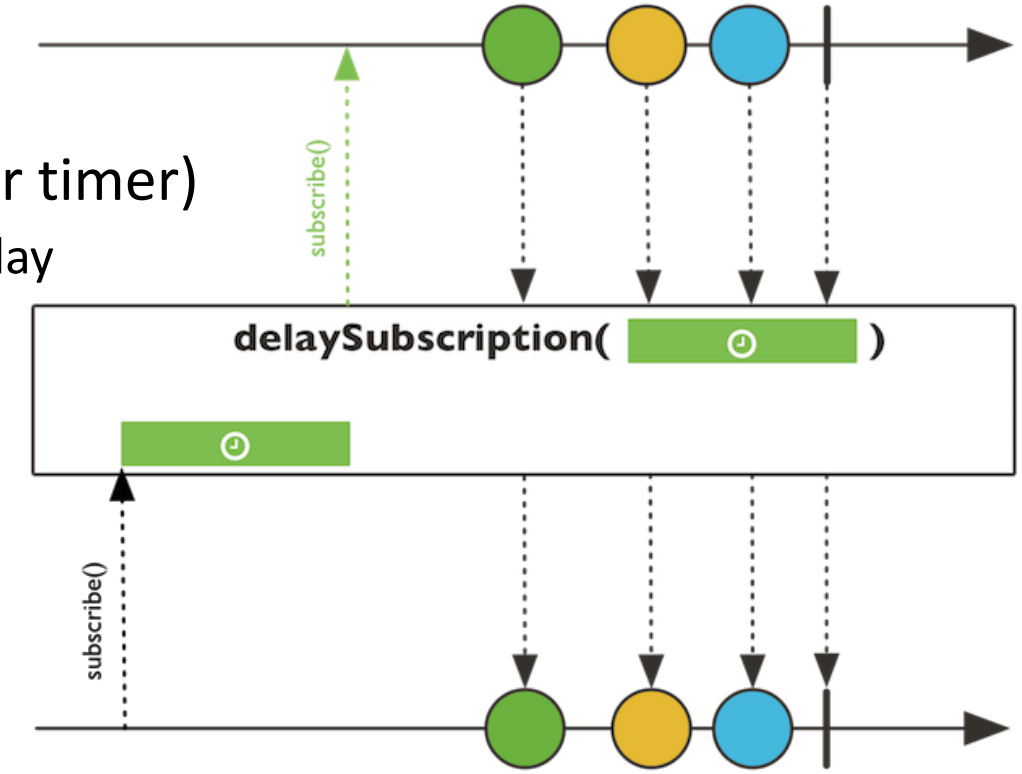
```
public Flux<Integer> fluxDelay(){
    return Flux.range(1,10).delayElements(Duration.ofMillis(100));
}
```

```
System.out.print("\n\nFlux Delay Elements: \n");
ex.fluxDelay().subscribe(System.out::print);
```

```
Flux Delay Elements:
12345678910
```

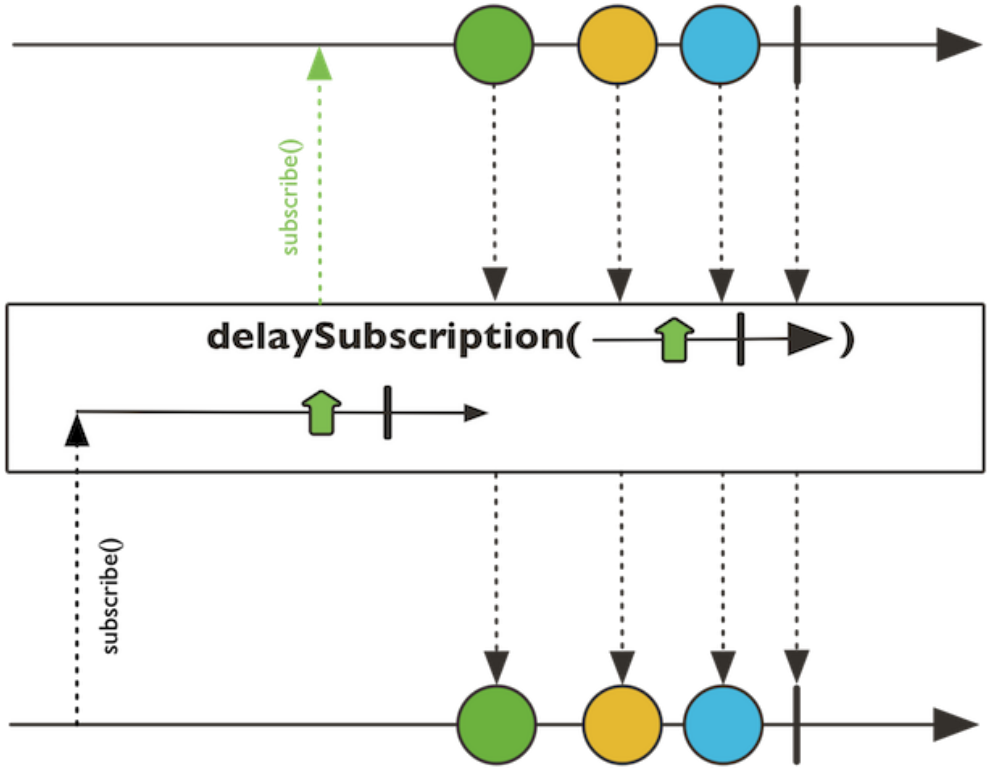
Flux

- Flux instance main methods:
  - delaySubscription(Duration delay)
  - delaySubscription(Duration delay, Scheduler timer)
    - blocks items subscription according to given delay



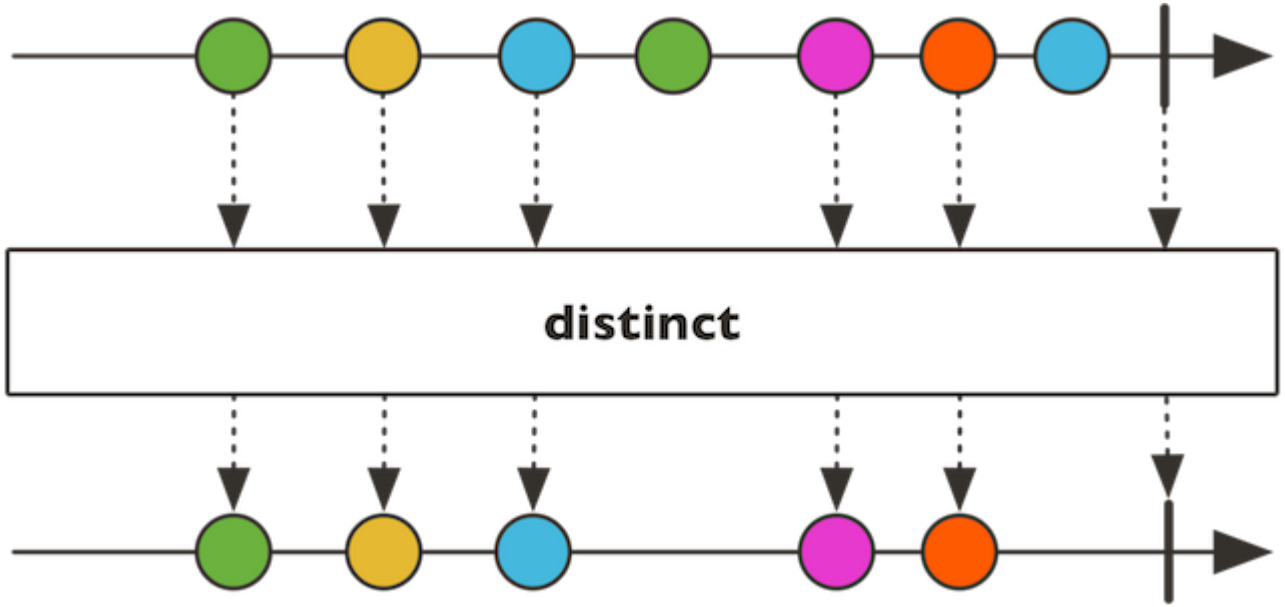
Flux

- Flux instance main methods:
  - delaySubscription(Publisher<T> source)
    - delays subscription until given publisher signals a value or completes



Flux

- Flux instance main methods:
  - distinct()
    - filters duplications for each subscriber



Flux

- Example:
  - distinct(…)

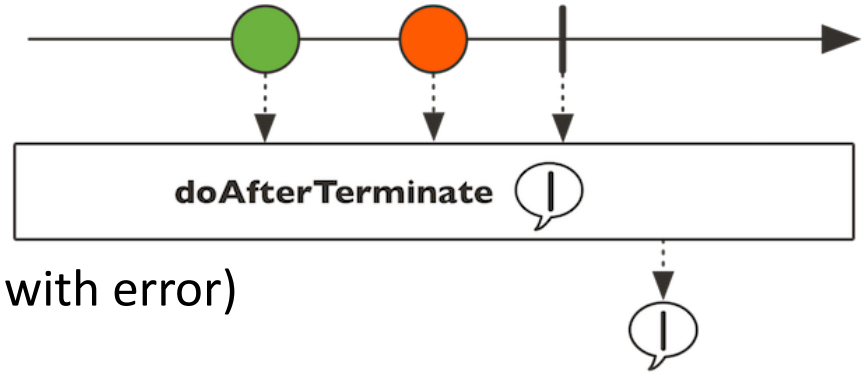
```
public Flux<Integer> fluxDistinct(){
   Flux<Integer> origin=Flux.fromArray(randomizeArray());
   System.out.print("Origin: ");
   origin.subscribe(System.out::print);
   System.out.println();
   return origin.distinct();
}
```

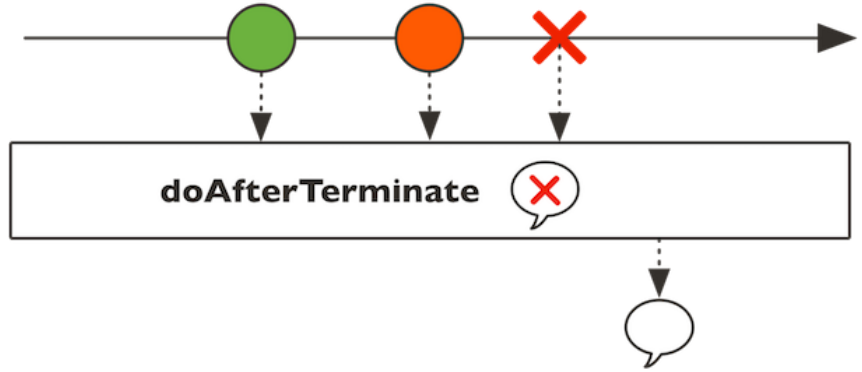
```
System.out.print("\n\nFlux Distinct: \n");
ex.fluxDistinct().subscribe(System.out::print);
```

```
Flux Distinct:
Origin: 10972391894345961675
1097238456
```

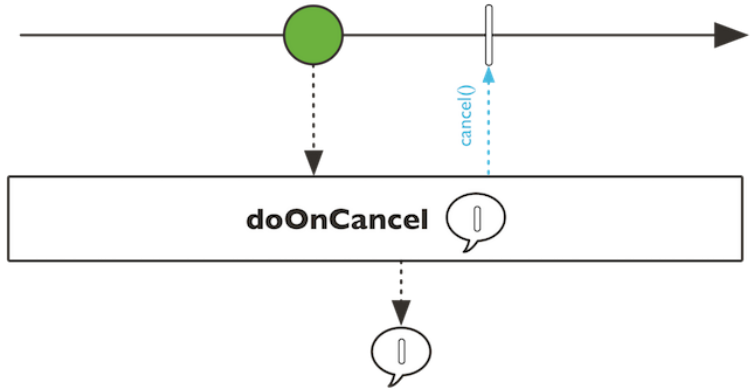
Flux

- Flux instance main methods:
  - doAfterTerminate(Runnable task)
    - executes task after stream completes (successfully of with error)



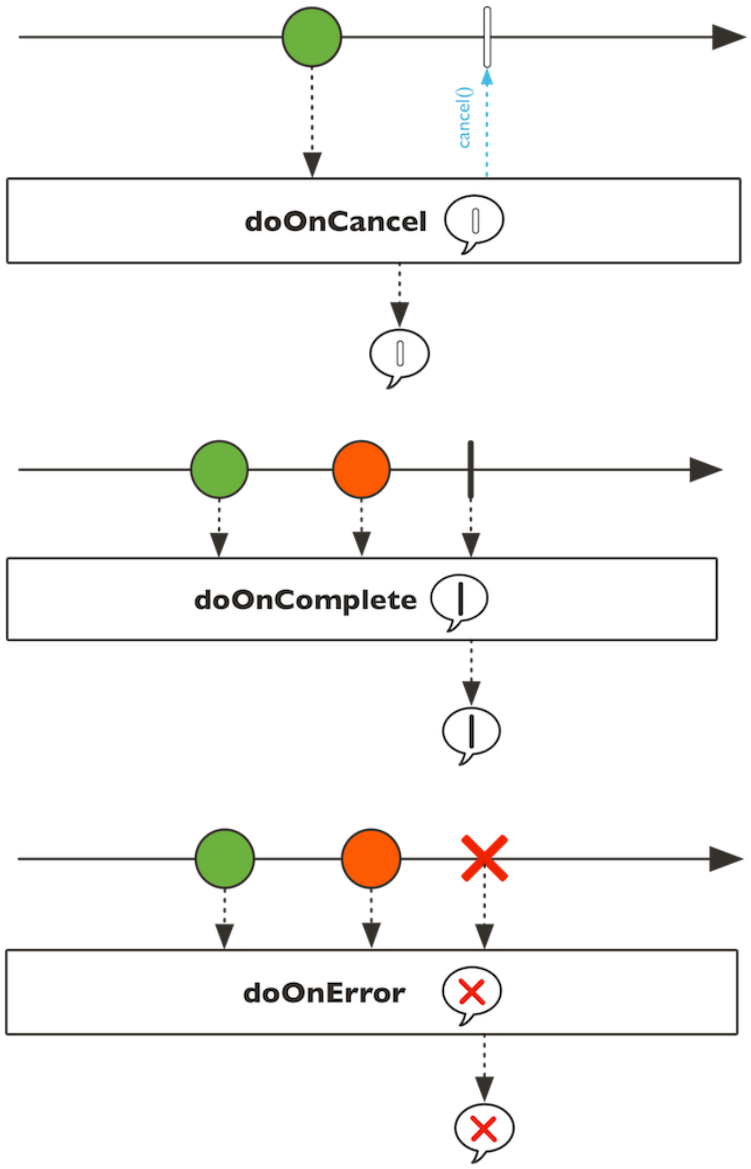


  - doOnCancel(Runnable task)
    - executes task when flux is canceled



Flux

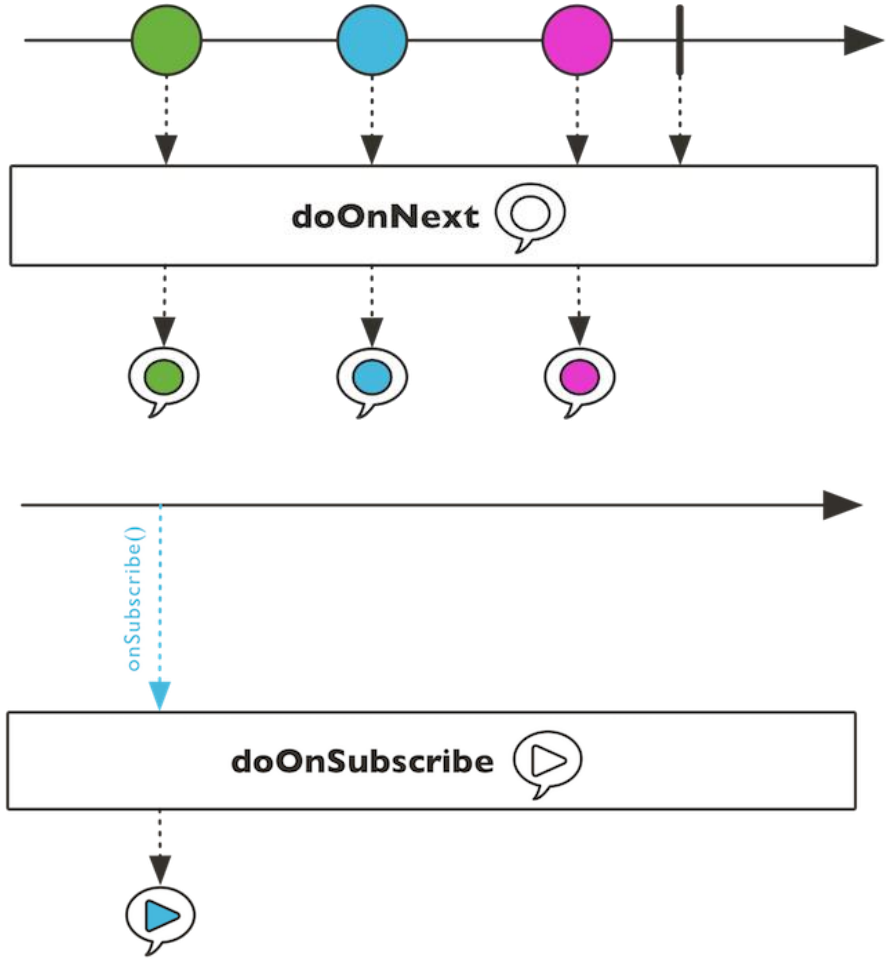
- Flux instance main methods:
  - doOnCancel(Runnable task)
    - executes task when flux is canceled
  - doOnComplete(Runnable task)
    - executes task when flux is completed successfully
  - doOnError(Consumer<Throwable> error)
    - passes error signal to given consumer



Flux

- Flux instance main methods:
  - doOnNext(Consumer<Signal<T>> signal)
    - passes onNext signals to given consumer
  - doOnSubscribe(Consumer<Signal<T>> signal)
    - passes onSubscribe signal to given consumer
  - doOnEach(Consumer<Signal<T>> signal)
    - passes any kind of signal to given consumer
    - signals: onNext, complete, error

T (item) can be recovered via Signal.get()



Flux

- Example:
  - doOnEach(…)

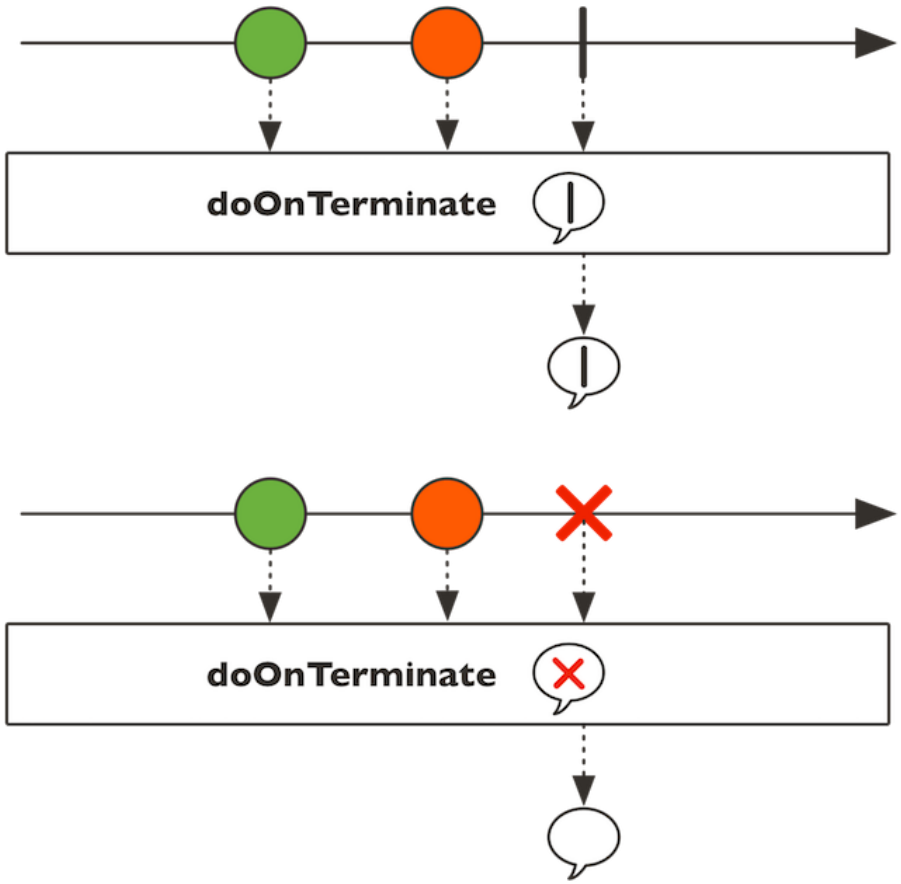
```
public Flux<Integer> fluxDoOnEach(){
   return Flux.range(1,10).doOnEach(signal->
                  {
                    if(signal.isOnNext())
                    System.out.print("_");
                    if(signal.isOnComplete())
                    System.out.print(" Done!");
                  });
}
```

```
System.out.print("\n\nFlux Do On Each: \n");
ex.fluxDoOnEach().subscribe(System.out::print);
```

```
Flux Do On Each:
_1_2_3_4_5_6_7_8_9_10 Done!
```

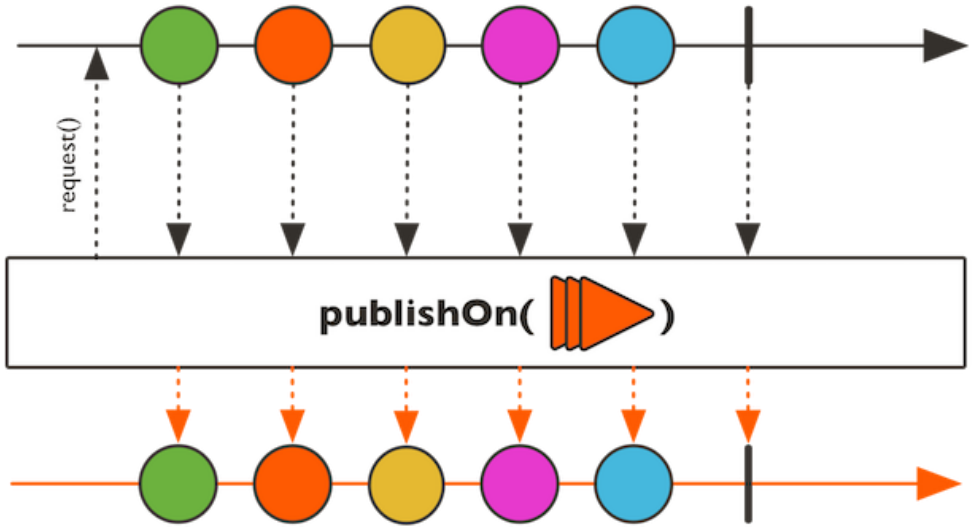
Flux

- Flux instance main methods:
  - doOnTerminate(Runnable task)
    - executes task on successful or error termination
  - doFinally(Consumer<SignalType> signal)
    - sends signal-type on successful or error termination



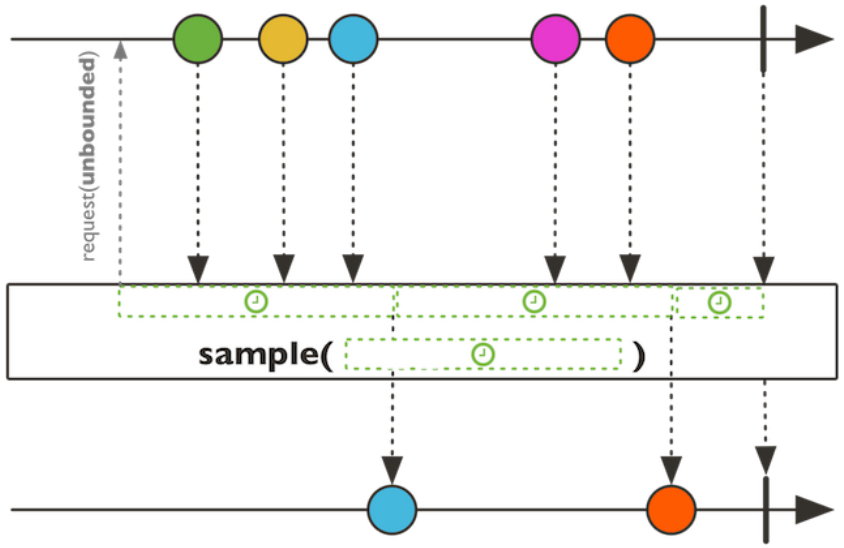
Flux

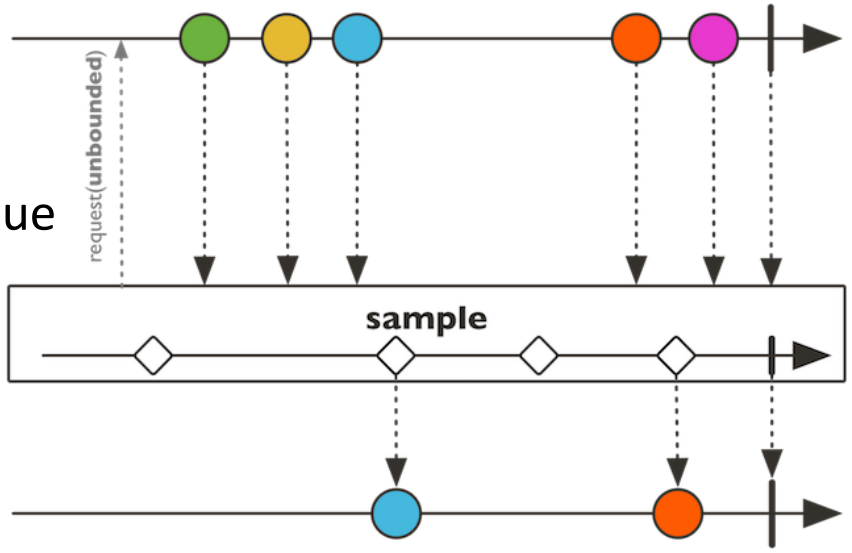
- Flux instance main methods:
  - publishOn(Scheduler scheduler)
  - publishOn(Scheduler scheduler, int prefetch)
    - Starts publishing according to scheduler



Flux

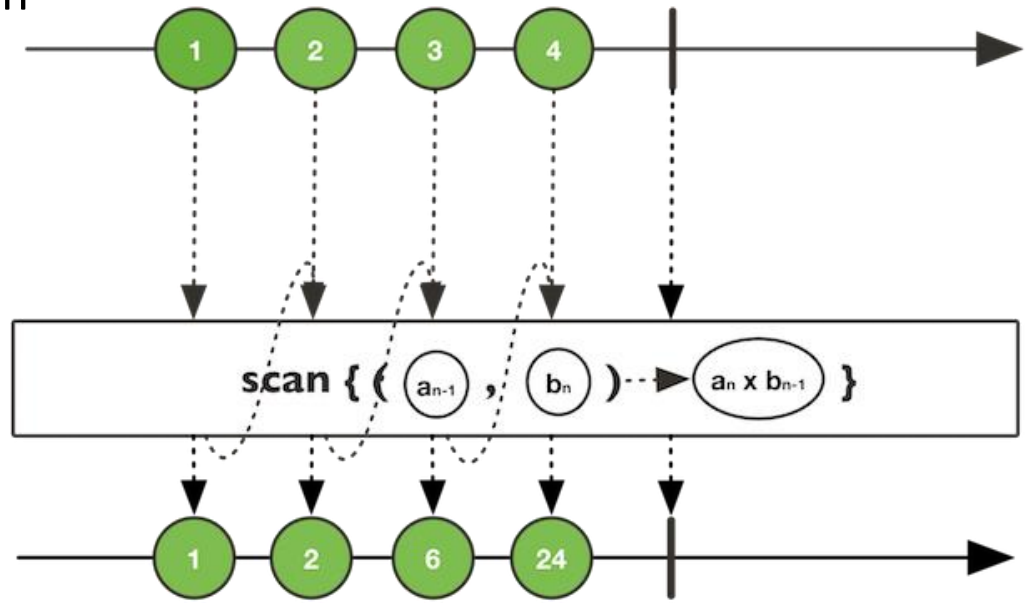
- Flux instance main methods:
  - sample(Duration timespan)
    - returns Flux<T> with latest emitted value within the periodical time window.
  - sample(publisher<U> sampler)
    - returns Flux<T> with latest emitted value in the current Flux<T> since sampler (Flux<U>) signaled a value
    - when one terminates - so does the other





Flux

- Flux instance main methods:
  - scan(BiFunction<T,T,T> reducer)
    - reduces every 2 last elements of current Flux<T> into new Flux<T> using given reducer function
    - function reduces T & T into T



Flux

- Example:
  - scan(…)

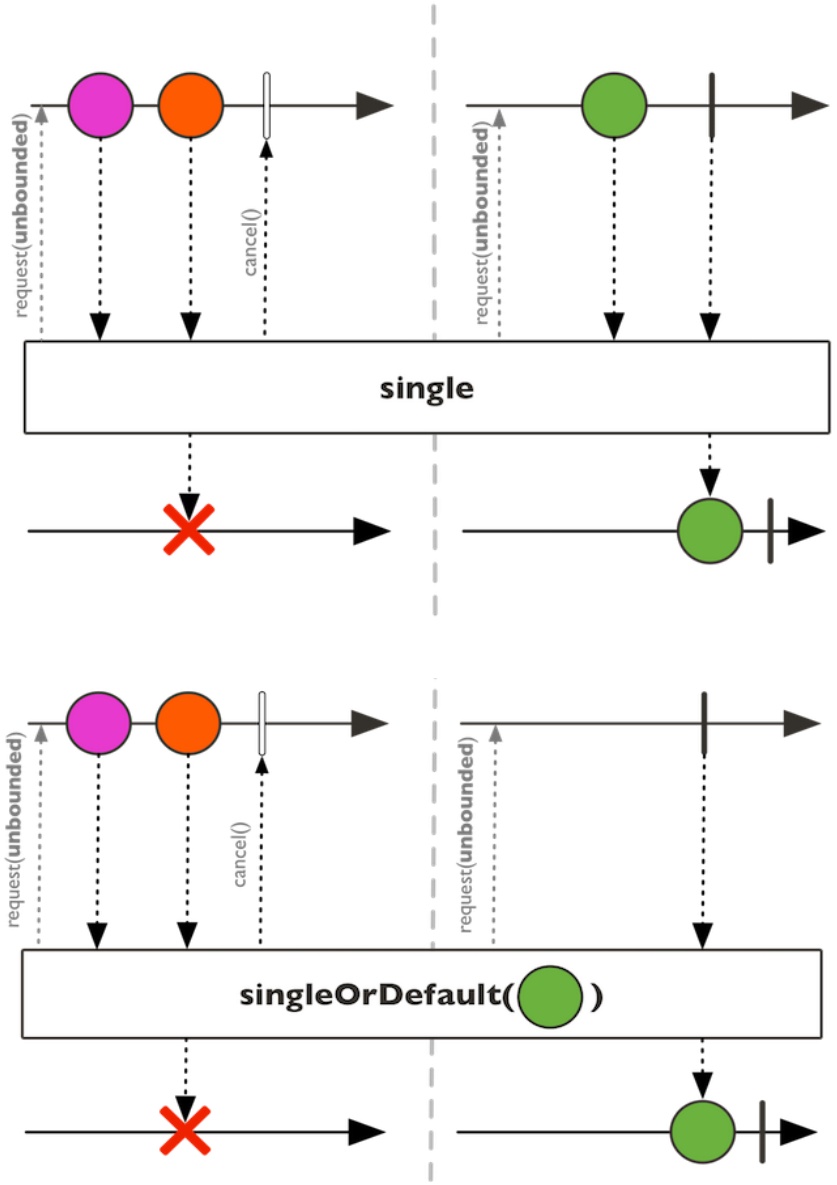
```
public Flux<Integer> fluxScan(){
     return Flux.range(0,11).scan((n1,n2)->n1+n2);
}
```

```
System.out.print("\n\nFlux Scan: \n");
ex.fluxScan().subscribe(System.out::println);
```

```
Flux Scan:
0
1
3
6
10
15
21
28
36
45
55
```

Flux

- Flux instance main methods:
  - singe()
    - returns Mono<T> when single value is emitted
    - Mono<T> contains emitted T value or null if empty
  - single(T value)
    - returns Mono<T> when single value is emitted
    - returns T value with Flux<T> ends empty
    - both result in IndexOutOfBoundsException if the stream has more than one element



Flux

- Example:
  - single(…)

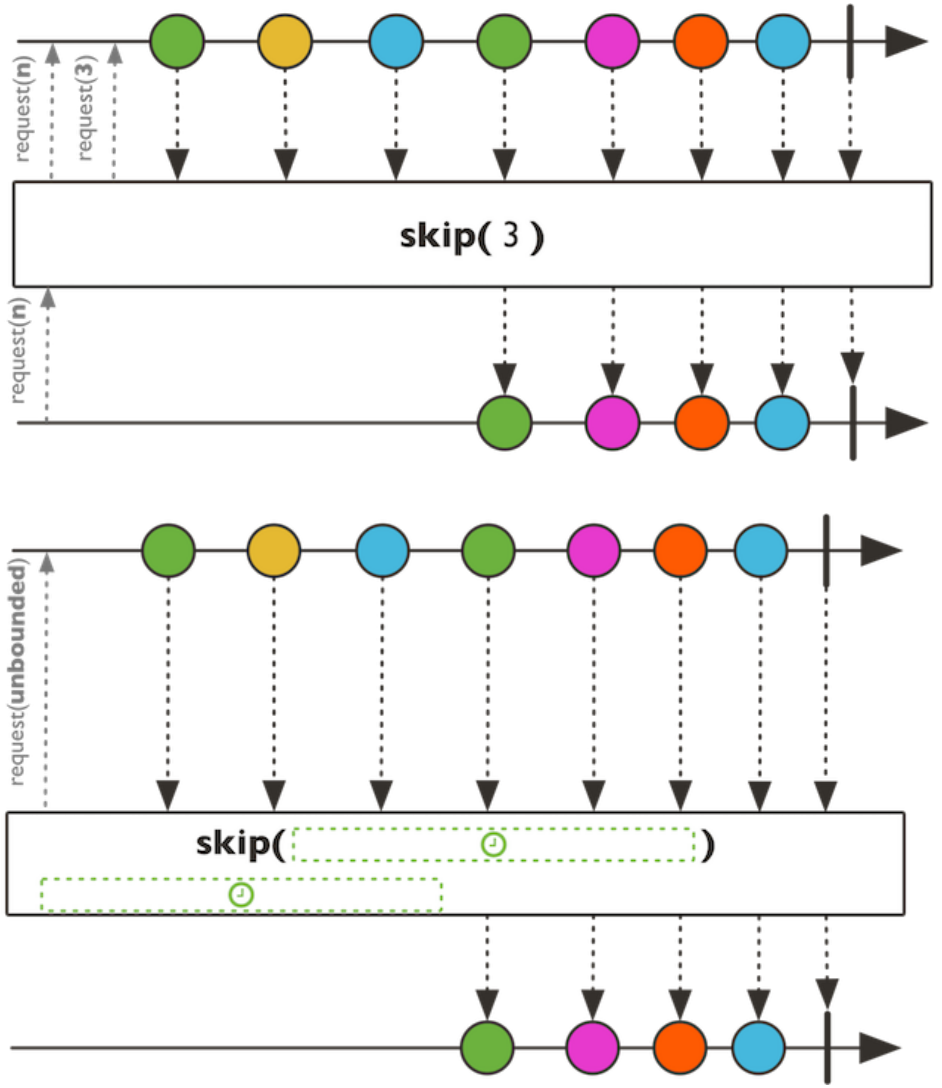
```
public Mono<Integer> fluxSingle(Integer...values){
   return Flux.fromArray(values).single(100);
}
```

```
System.out.print("\n\nFlux Single: \n");
ex.fluxSingle().subscribe(System.out::println);
ex.fluxSingle(50).subscribe(System.out::println);
```

```
Flux Single:
100
50
```

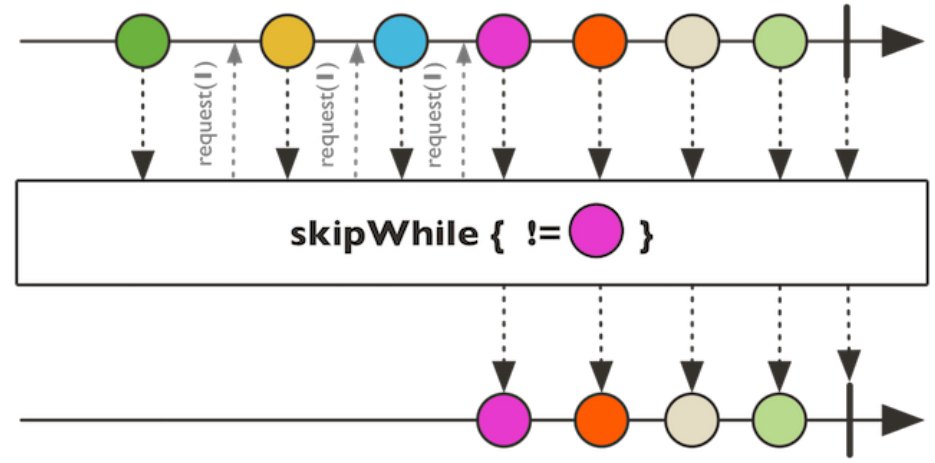
Flux

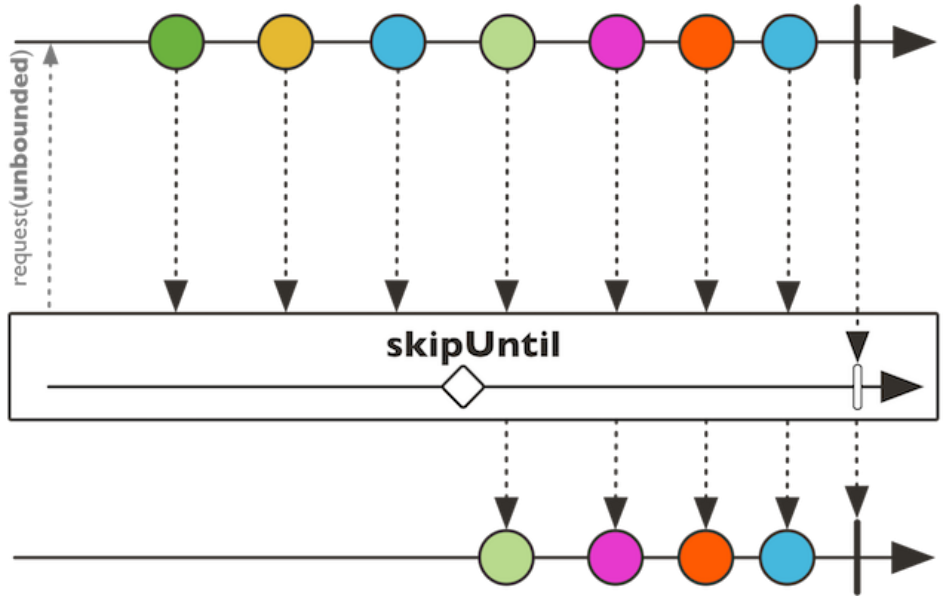
- Flux instance main methods:
  - skip(long skipped)
    - skips specified number of items from the beginning of the steam and emits the rest
  - skip(Duration timespan)
  - skip(Duration timespan, Scheduler timer)
    - skips items signaled during timespan



Flux

- Flux instance main methods:
  - skipWhile(Predicate<T> test)
    - skips items from this stream while test returns ‘true’ for a value
  - skipUntil(Predicate<T> test)
    - skips items from this stream until test returns ‘true’ for a value
  - skipUntilOther(Publisher<?> other)
    - skips items from this stream until ‘other’ signals onNext / onComplete





Flux

- Example:
  - skip(…)

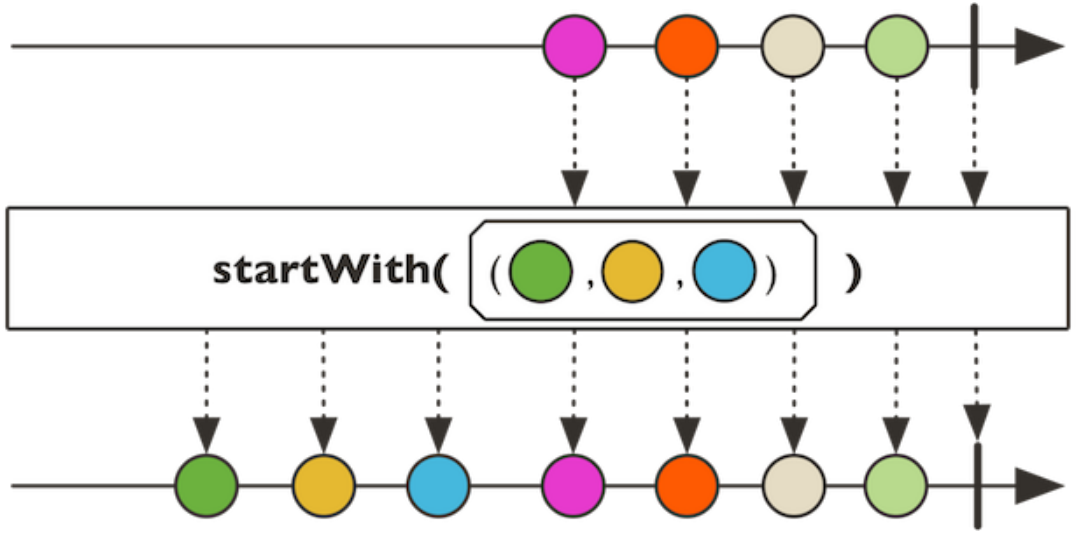
```
public Flux<Integer> fluxSkip(int startFrom){
    return Flux.range(0,10).skip(startFrom);
}
```

```
System.out.print("\n\nFlux Skip: \n");
ex.fluxSkip(5).subscribe(System.out::print);
```

```
Flux Skip:
56789
```

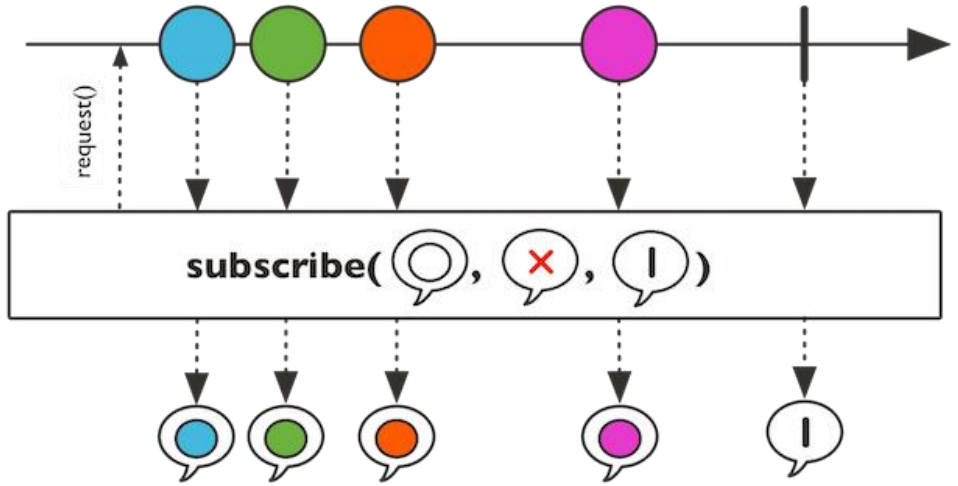
Flux

- Flux instance main methods:
  - sort()
  - sort(Comparator<T> comparator)
    - returns a sorted Flux<T>
  - startWith(Iterable<T> startItems)
  - startWith(T… startItems)
  - startWith(Publisher<T> startItems)
    - pre-ends startItems before stream values



Flux

- Flux instance main methods:
  - subscribe()
    - returns Disposable when no further processing is required (Disposable.dispose())
  - subscribe(Consumer<T> handler, Consumer<Throable> errHandler)
  - subscribe(Consumer<T> handler, Consumer<Throable> errHandler, Runnable task)
    - handler – consumes T stream values
    - errHandler – consumes error termination
    - task – is executed on completion



Flux

- Example:
  - subscribe(…) & Disposable.dispose()

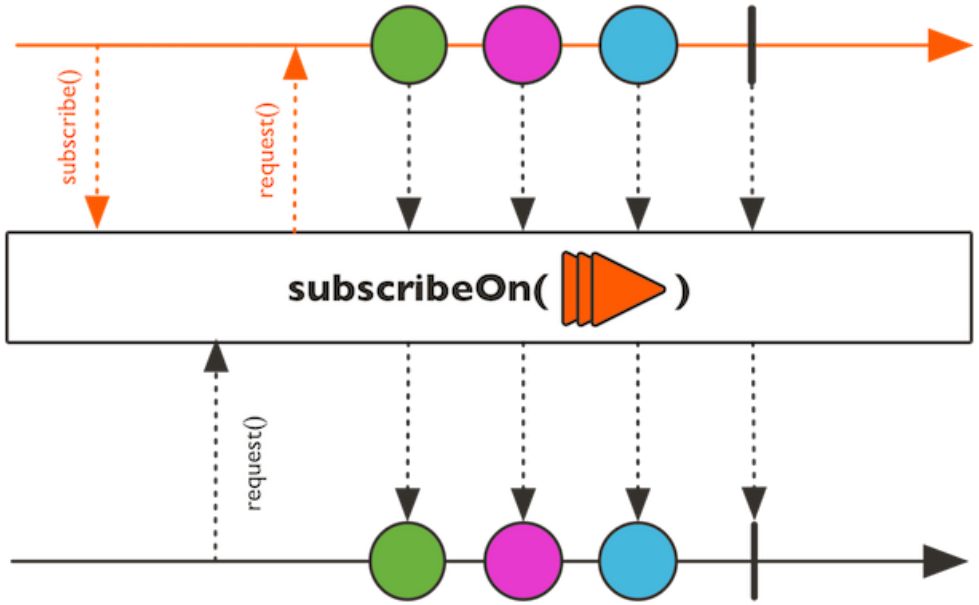
```
public void fluxDispose(){
     Disposable d=Flux.interval(Duration.ofMillis(100)).subscribe(System.out::print);
     try {Thread.sleep(1000);}catch (Exception e) {}
     d.dispose();
}
```

```
System.out.print("\n\nFlux Dispose Subscription: \n");
ex.fluxDispose();
```

```
Flux Dispose Subscription:
0123456789
```

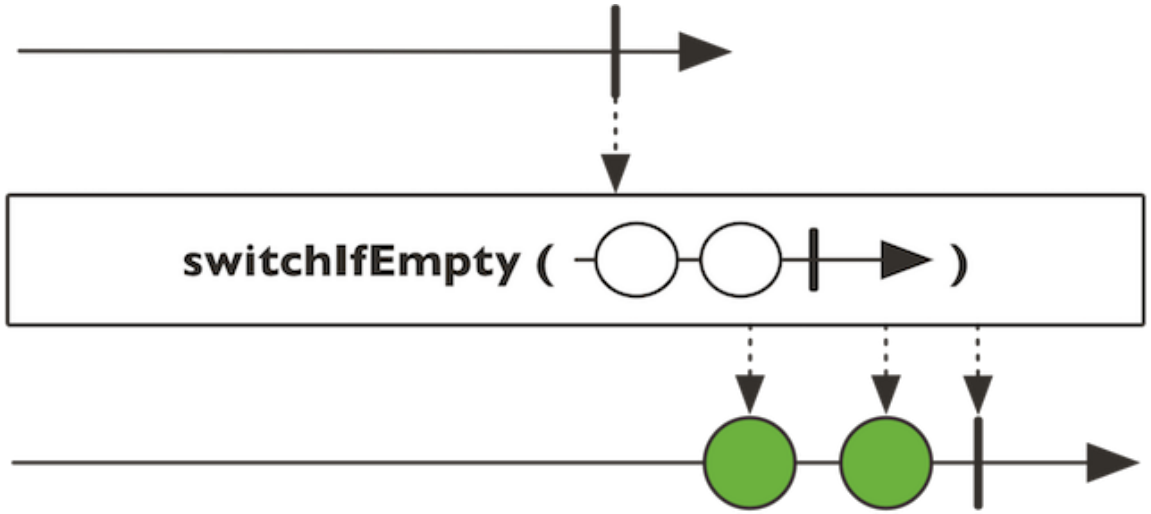
Flux

- Flux instance main methods:
  - subscribeOn(Scheduler scheduler)
    - starts subscription according to scheduler



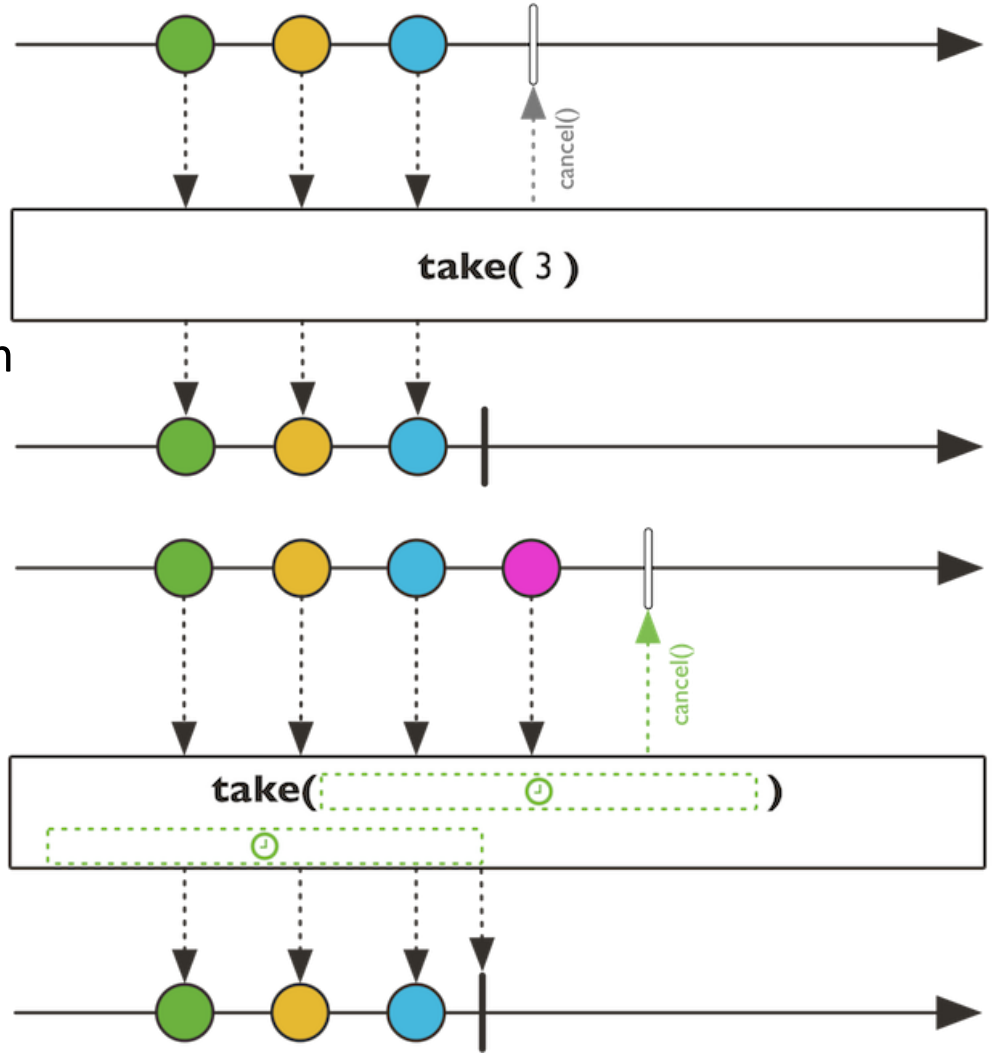
Flux

- Flux instance main methods:
  - switchIfEmpty(Publisher<T> alternate)
    - Switches to alternate stream if current stream terminates empty



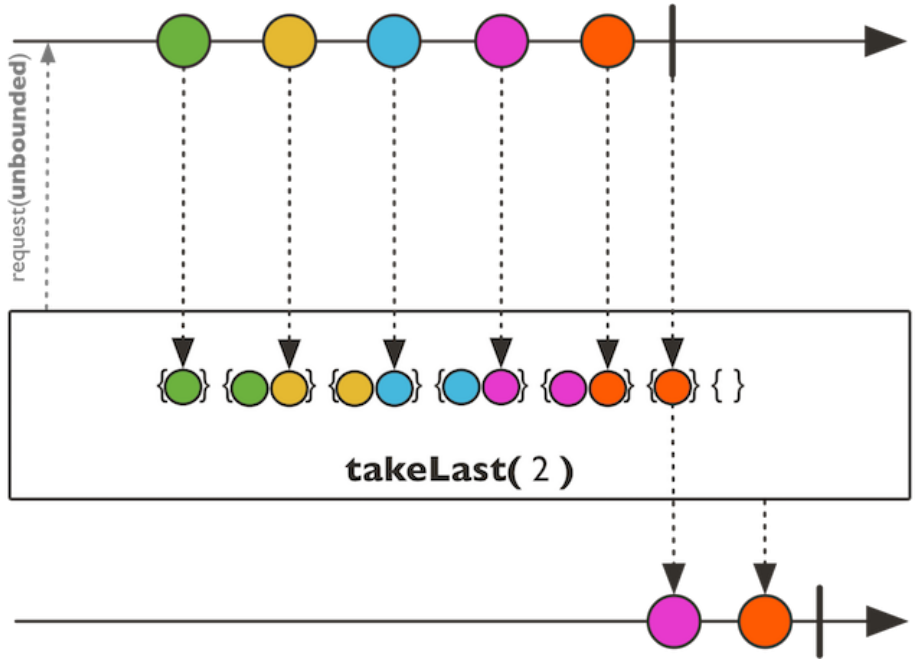
Flux

- Flux instance main methods:
  - take(long numOfItems)
    - returns Flux<T> with only first ‘numOfItems’ from current stream
  - take(Duration delay)
  - take(Duration delay, Scheduler timer)
    - returns values until ‘delay’ expires



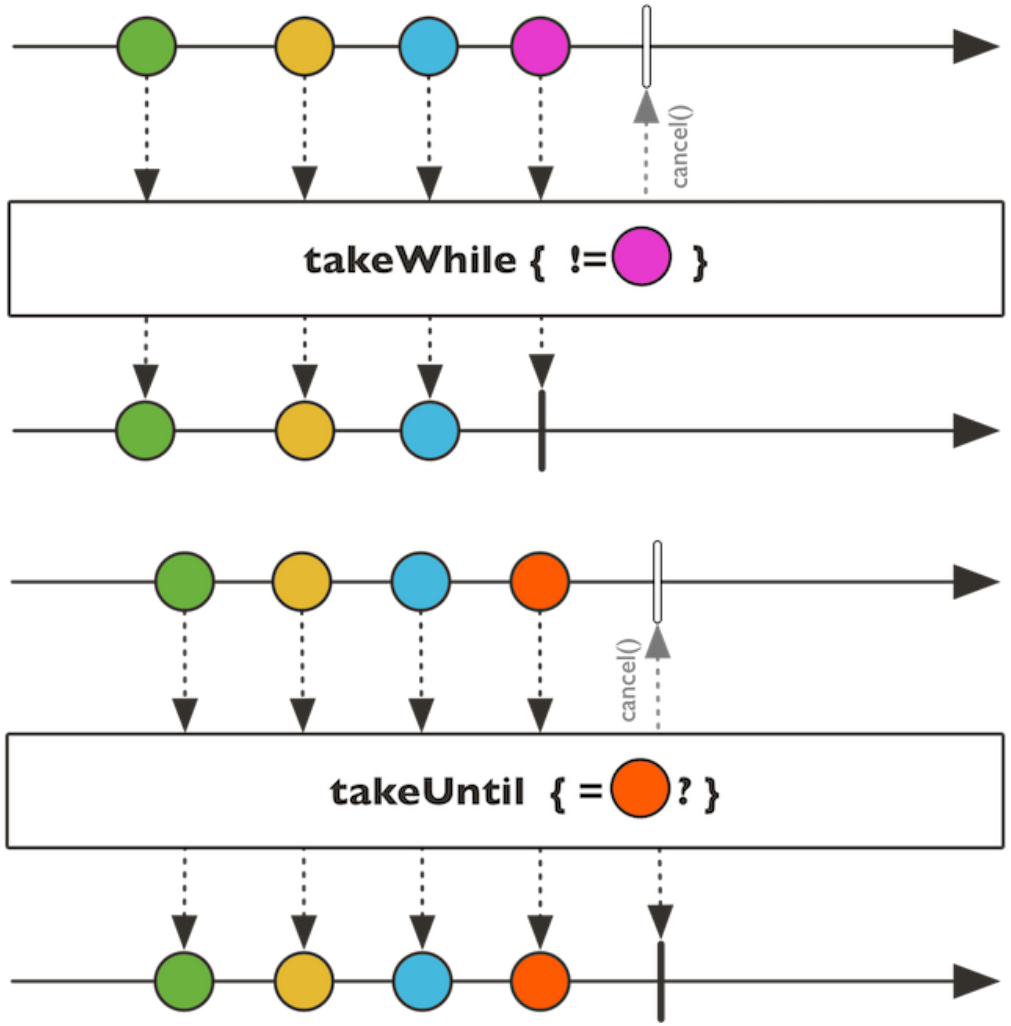
Flux

- Flux instance main methods:
  - takeLast(long numOfItems)
    - returns Flux<T> with only last ‘numOfItems’ from current stream



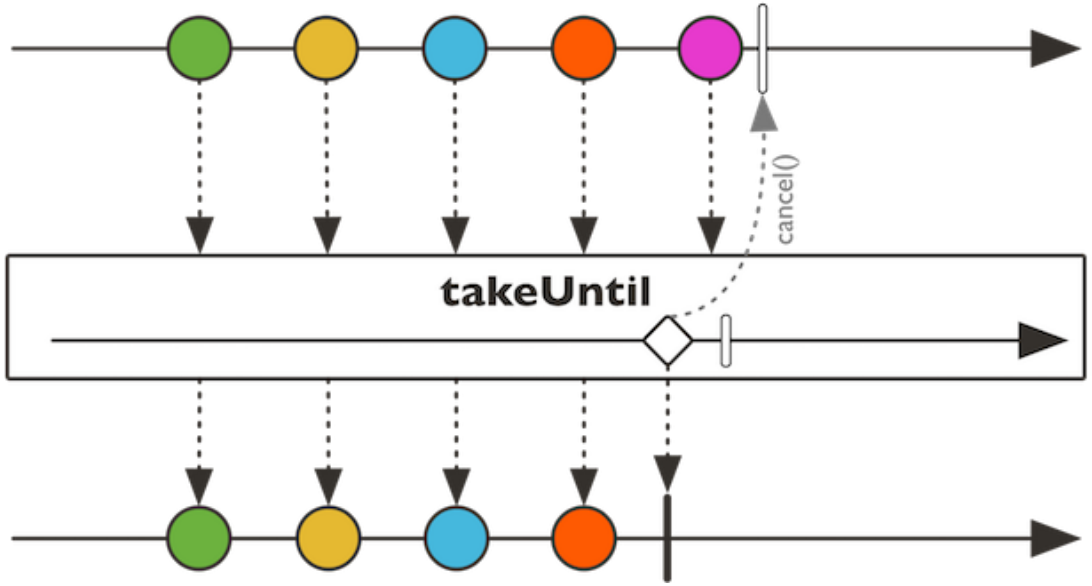
Flux

- Flux instance main methods:
  - takeWhile (Predicate<T> test)
    - returns values while T passes given test
  - takeUntil(Predicate<T> test)
    - returns values until T passes given test



Flux

- Flux instance main methods:
  - takeUntilOther(Publisher<T> other)
    - returns values until other signals onNext or completes



Flux

- Example:
  - take(…)

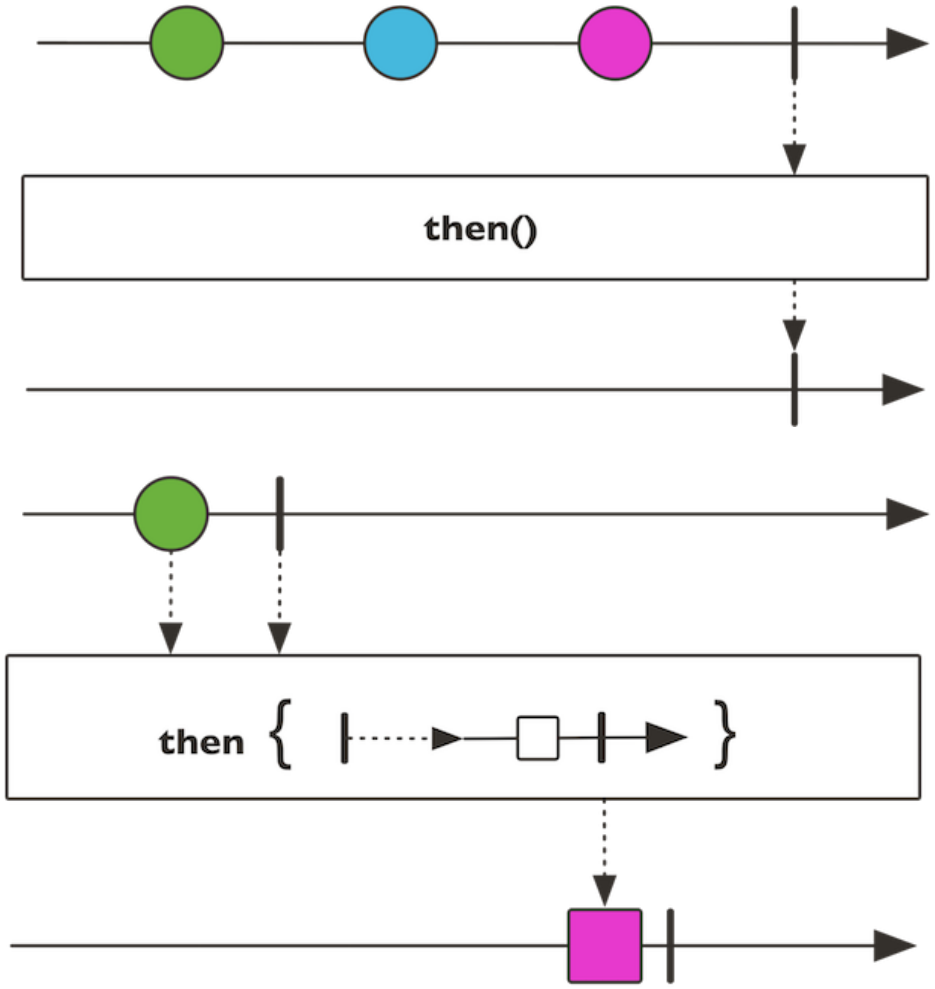
```
public Flux<Integer> fluxTake(int endAt){
    return Flux.range(0,10).take(endAt);
}
```

```
System.out.print("\n\nFlux Take: \n");
ex.fluxTake(5).subscribe(System.out::print);
```

```
Flux Take:
01234
```

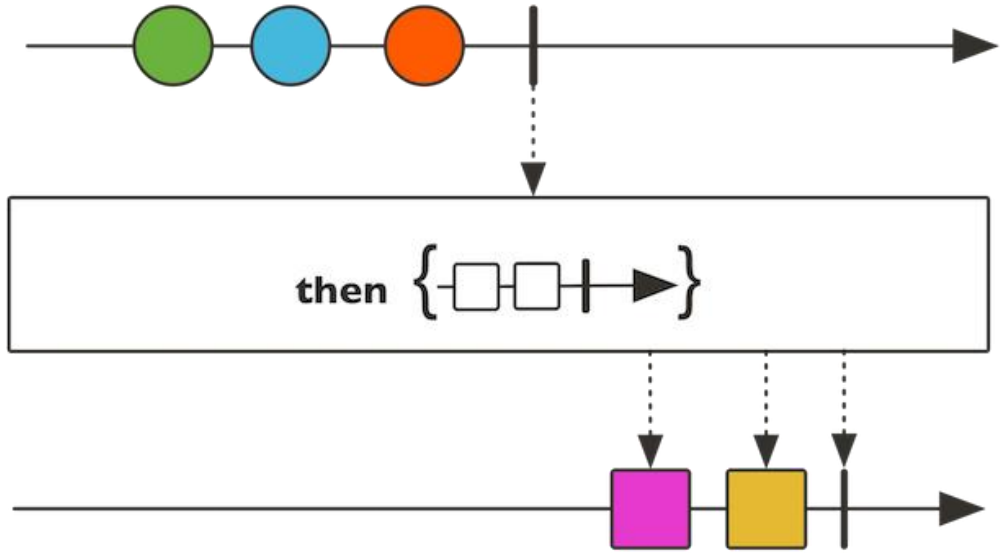
Flux

- Flux instance main methods:
  - then()
    - returns Mono<Void> on completion (successfully or with error)
  - then(Mono<V>)
    - returns Mono<V> on completion
    - errors are delegated to Mono<V>



Flux

- Flux instance main methods:
  - thenMany(Publisher<V> other)
    - plays given stream when current Flux<T> completes
    - returns Flux<V>



Flux

- Example:
  - than(…)

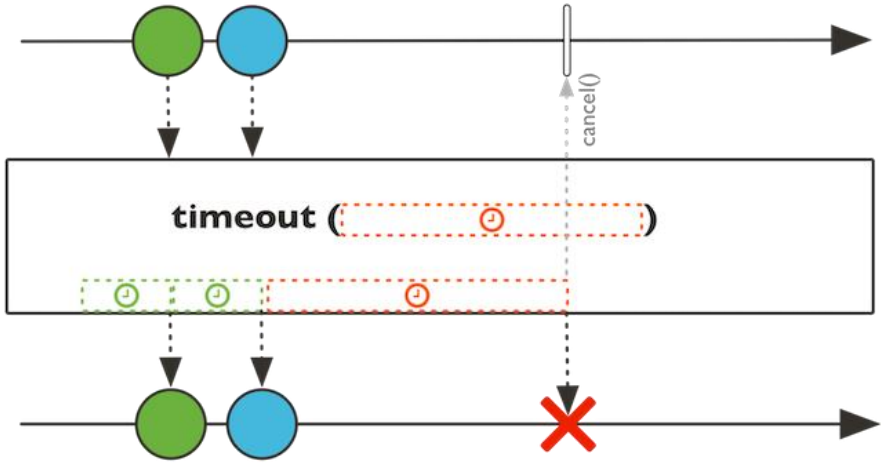
```
public Flux<?> fluxThenMany(){
     return Flux.range(0,10).doOnNext(System.out::print).thenMany(fluxFrom());
}
```

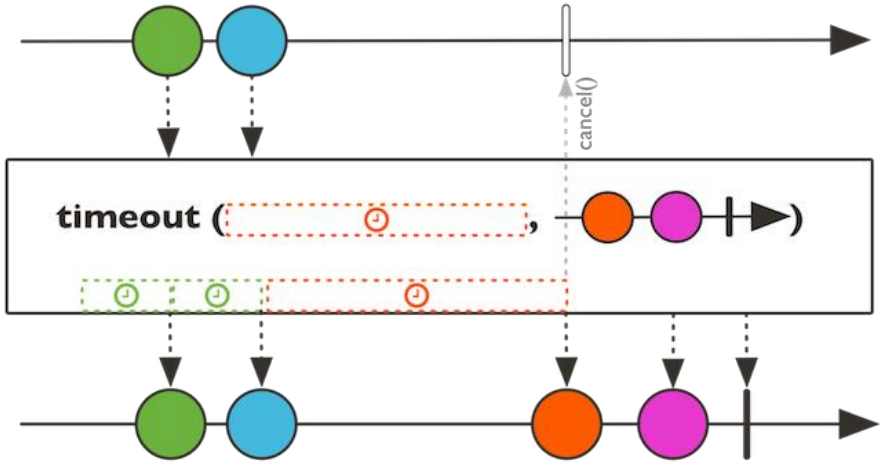
```
System.out.print("\n\nFlux Then Many: \n");
ex.fluxThenMany().subscribe(System.out::print);
```

```
Flux Then Many:
0123456789aaabbbccc
```

Flux

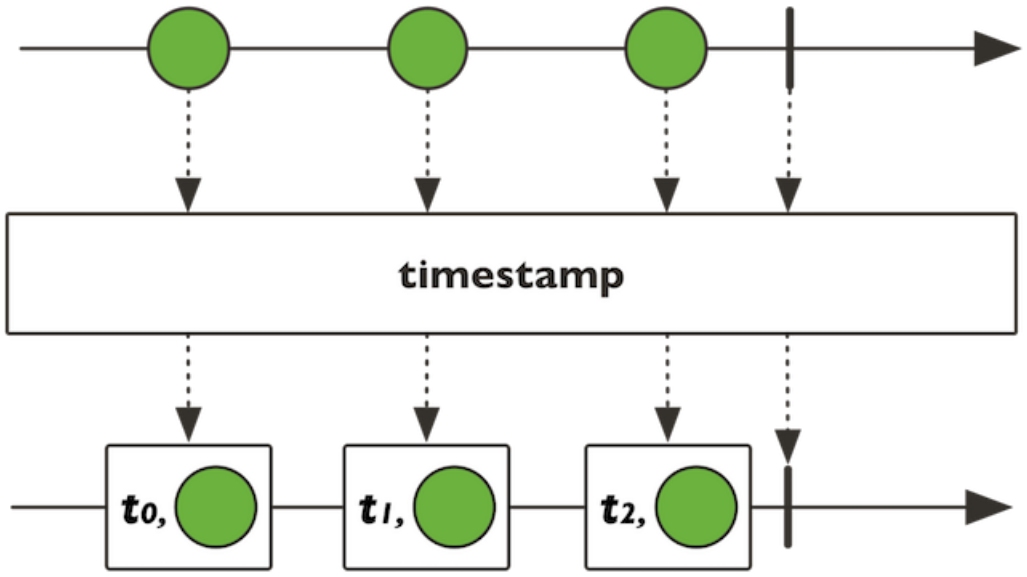
- Flux instance main methods:
  - timeout(Duration timeout)
    - propagates TimeoutException if no item emitted within given timeout
  - timeout(Duration timeout, Publisher<T> fallback)
    - fallbacks to given publisher if no item emitted within given timeout





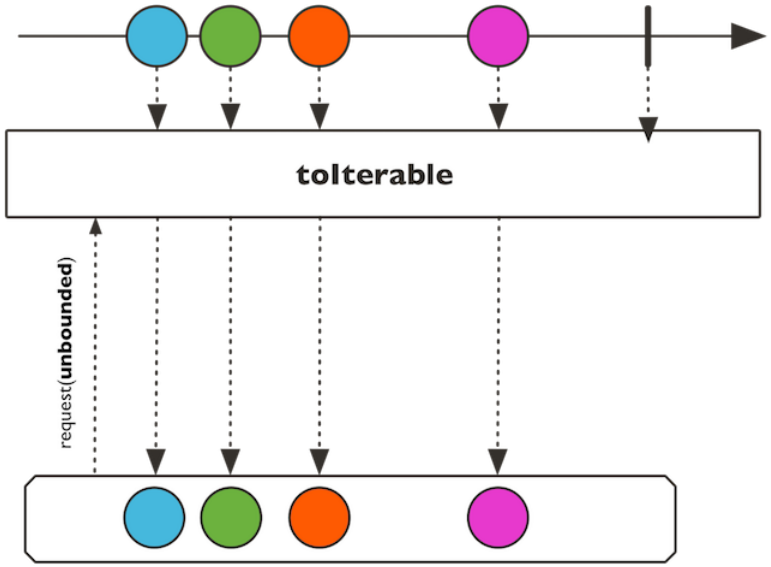
Flux

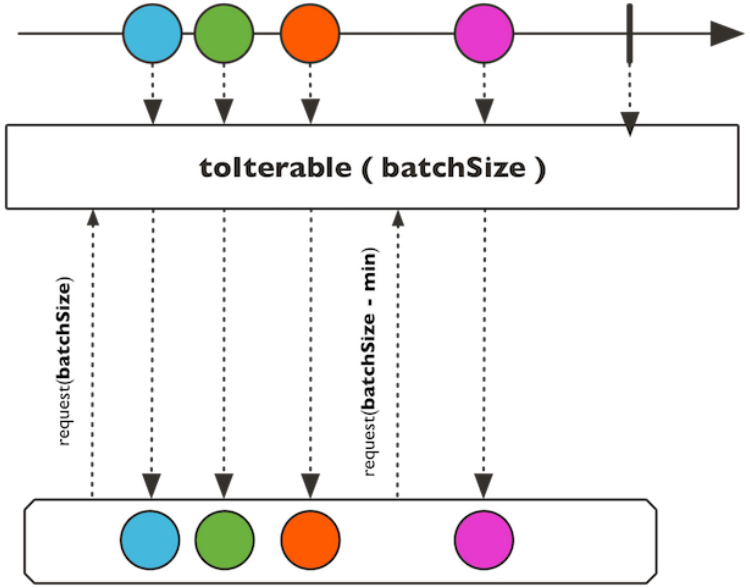
- Flux instance main methods:
  - timestamp()
    - returns Flux<Tuple2<Long,T>>
    - Long is current timestamp attached to item T
  - timestamp(Scheduler scheduler)
    - returns Flux<Tuple2<Long,T>>
    - Long is given scheduler current timestamp



Flux

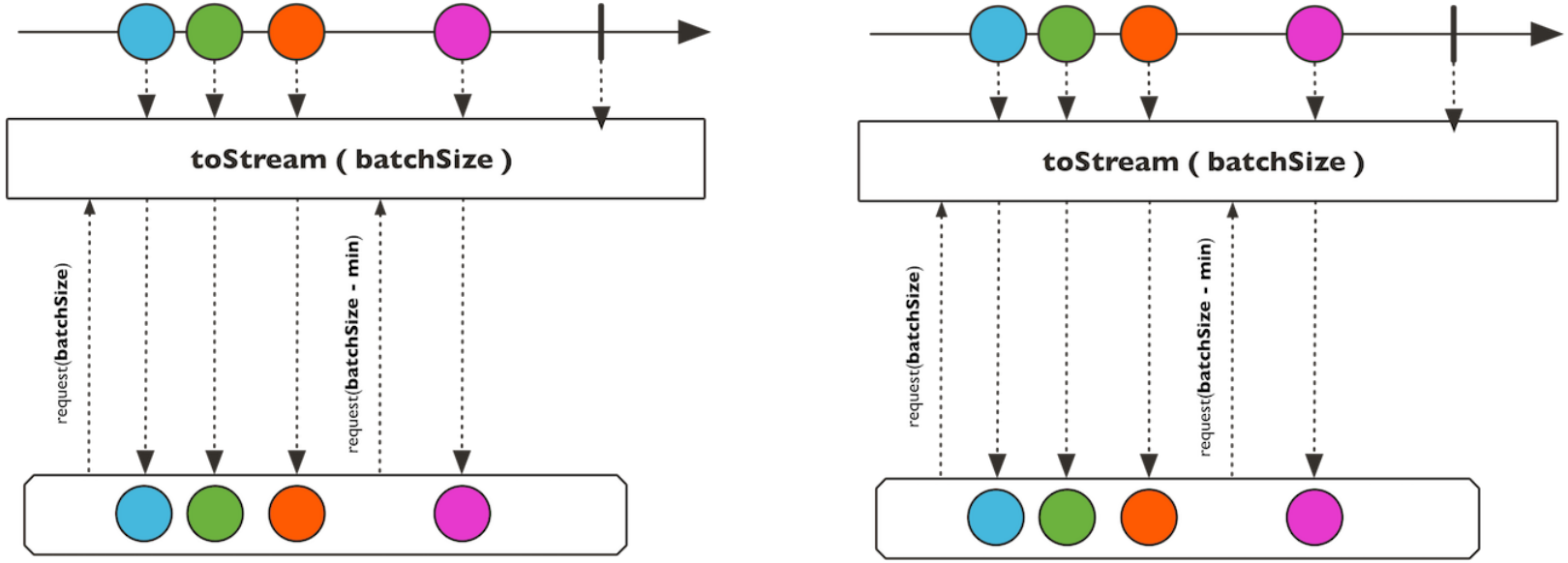
- Flux instance main methods:
  - toIterable()
  - toIterable(int batchSize)
    - returns blocking Iterable<T>





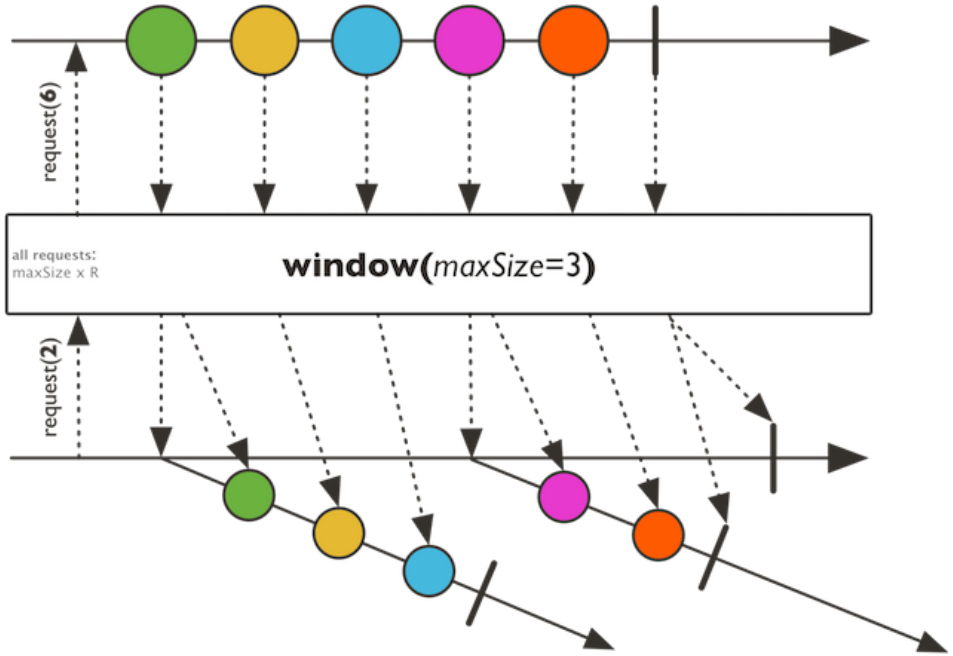
Flux

- Flux instance main methods:
  - toStream()
  - toStream(int batchSize)
    - returns Stream<T> which blocks for source onNext calls



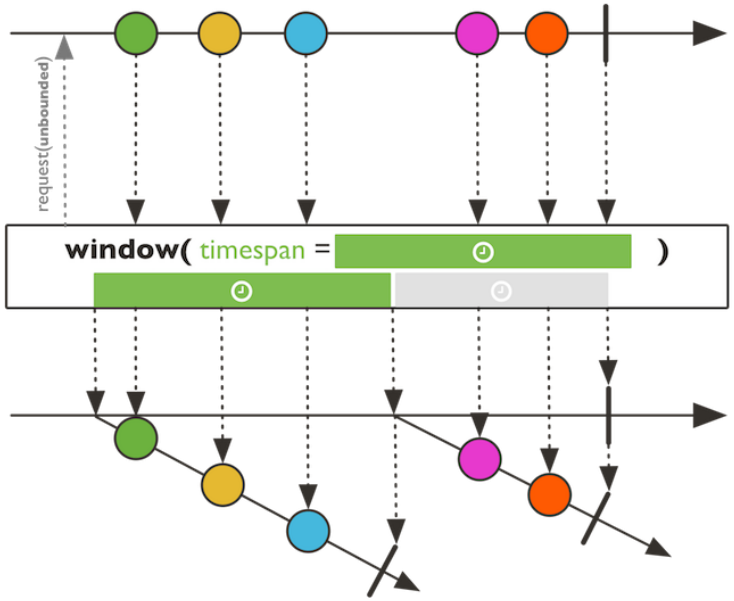
Flux

- Flux instance main methods:
  - transform(Function <Flux<T>, Publisher<V>)
    - transforms Flux<T> into Flux<V> with given mapper
  - window(int maxSize)
    - splits Flux<T> into multiple Flux<T> with given maxSize
    - returns Flux<Flux<T>>



Flux

- Flux instance main methods:
  - window(Duration timespan)
  - window(Duration timespan , Duration timeshift)
    - splits Flux<T> into multiple Flux<T> every period of time specified as ‘timespan’
    - timeshift specifies intervals
    - window() versions with Scheduler are also available
    - returns Flux<Flux<T>>



Flux

- Example:
  - window(…)

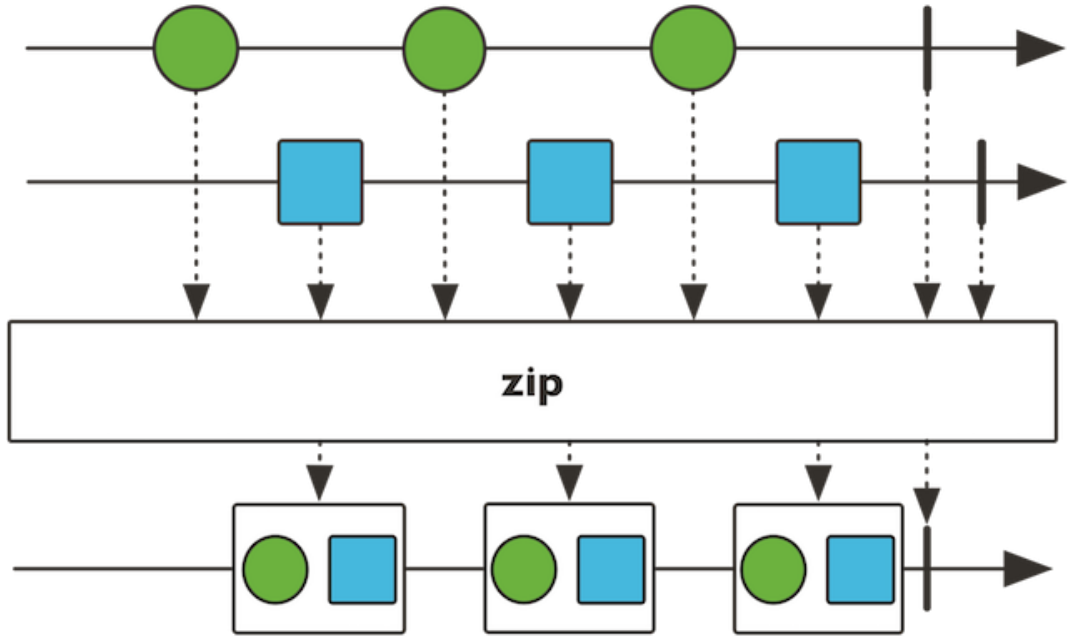
```
public Flux<Flux<Integer>> fluxWindow(){
    return Flux.range(0,10).window(3).doOnNext(s->System.out.print(" window: "));
}
```

```
System.out.print("\n\nFlux Window: \n");
ex.fluxWindow().subscribe(flux->flux.subscribe(System.out::print));
```

```
Flux Window:
 window: 012 window: 345 window: 678 window: 9
```

Flux

- Flux instance main methods:
  - zipWith(Publisher<V> other)
    - merges current Flux<T> with Publisher<V>
  - zipWithItarable(Publisher<V> other)
    - merges current Flux<T> with Iterable<V>
    - results in Flux<Tuple2<T,V>>



Flux

- Example:
  - zipWith(…)

```
public Flux<Tuple2<Integer, String>> fluxZipWith(){
     return Flux.range(1,3).zipWith(fluxFrom());
}
```

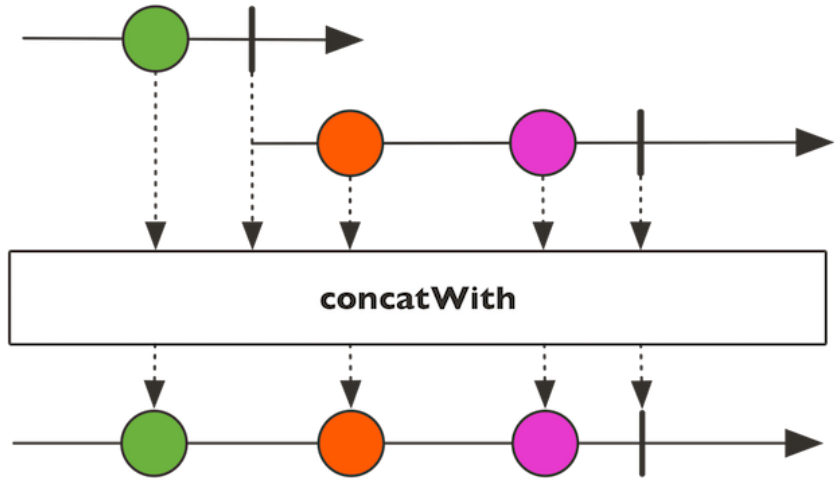
```
System.out.print("\n\nFlux Zip With: \n");
ex.fluxZipWith().subscribe(tuple2->System.out.println(tuple2.getT1()+"-"+tuple2.getT2()));
```

```
Flux Zip With:
1-aaa
2-bbb
3-ccc
```

Mono to Flux

Mono to Flux

- Turning Mono into Flux:
  - concatWith(Publisher<T> publisher)
    - Appends given Publisher to current Mono<T>
    - no interleave – all items become one Flux



Mono to Flux

- Example:
  - concatWith(…)

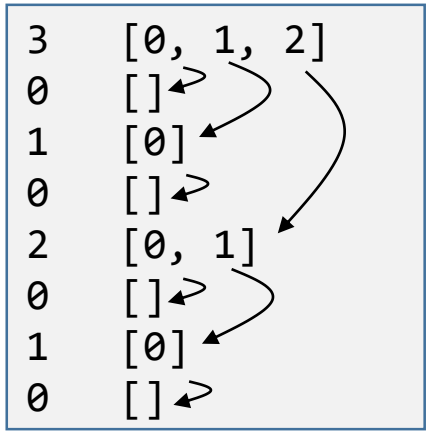
```
public Flux<String> monoConcat(){
    return Mono.just("Hello").concatWith(Flux.just(" ","Reactive"," ","World","!"));
}
```

```
System.out.print("\n\nMono to Flux - Concat: \n");
ex.monoConcat().subscribe(System.out::print);
```

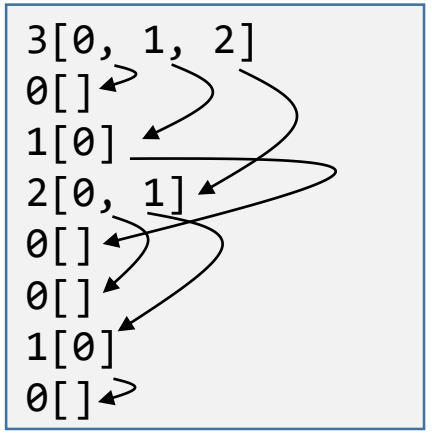
```
Mono to Flux - Concat:
Hello Reactive World!
```

Mono to Flux

- Turning Mono into Flux:
  - expand(Function<T, Publisher<T> publisher)
    - applies function to current Mono<T> value
    - recursively applies function to each of the generated values
    - uses breadth-first traversal strategy
    - for example, if function turns Mono{3} into Flux{1,2,3} the result will be:



  - expandDeep(Function<T, Publisher<T> publisher)
    - does the same but uses deep-first strategy
    - for example, if function turns Mono{3} into Flux{1,2,3} the result will be:



Mono to Flux

- Example:
  - expand(…)

```
public Flux<Integer> monoExpand(int value){
    return Mono.just(value).expand(val->{
                    List<Integer> data=new ArrayList<>();
                    for(int i=0;i<val;i++){
                         data.add(i);
                    }
                    System.out.println(data);
                    return Flux.fromIterable(data);
                    });
}
```

```
System.out.print("\n\nMono to Flux - Expand: \n");
ex.monoExpand(3).subscribe(System.out::print);
```

```
ono to Flux - Expand:
3[0, 1, 2]
0[]
1[0]
2[0, 1]
0[]
0[]
1[0]
0[]
```

Mono to Flux

- Example:
  - expandDeep(…)

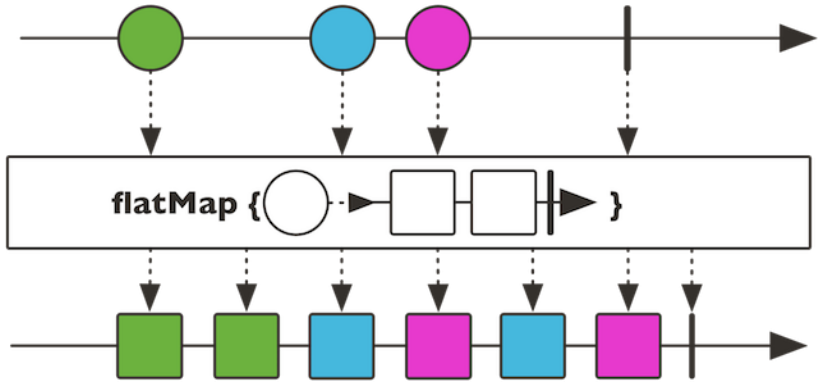
```
public Flux<Integer> monoExpand(int value){
    return Mono.just(value).expandDeep(val->{
                    List<Integer> data=new ArrayList<>();
                    for(int i=0;i<val;i++){
                         data.add(i);
                    }
                    System.out.println(data);
                    return Flux.fromIterable(data);
                    });
}
```

```
System.out.print("\n\nMono to Flux – Expand Deep: \n");
ex.monoExpand(3).subscribe(System.out::print);
```

```
Mono to Flux - Expand Deep:
3[0, 1, 2]
0[]
1[0]
0[]
2[0, 1]
0[]
1[0]
0[]
```

Mono to Flux

- Turning Mono into Flux:
  - flatMapIterable(Function<T, Iterable<R>> mapper)
    - transforms <T> emitted by current Mono into Flux<R>
    - uses a mappers to map T into Iterable<R>
  - flatMapMany(Function<T, Publisher<R>> mapper)
    - transforms <T> emitted by current Mono into Flux<R>
    - uses a mappers to map T into Publisher<R>
  - flux()
    - converts this Mono<T> to Flux<T>



Mono to Flux

- Example:
  - flatMapIterable(…)

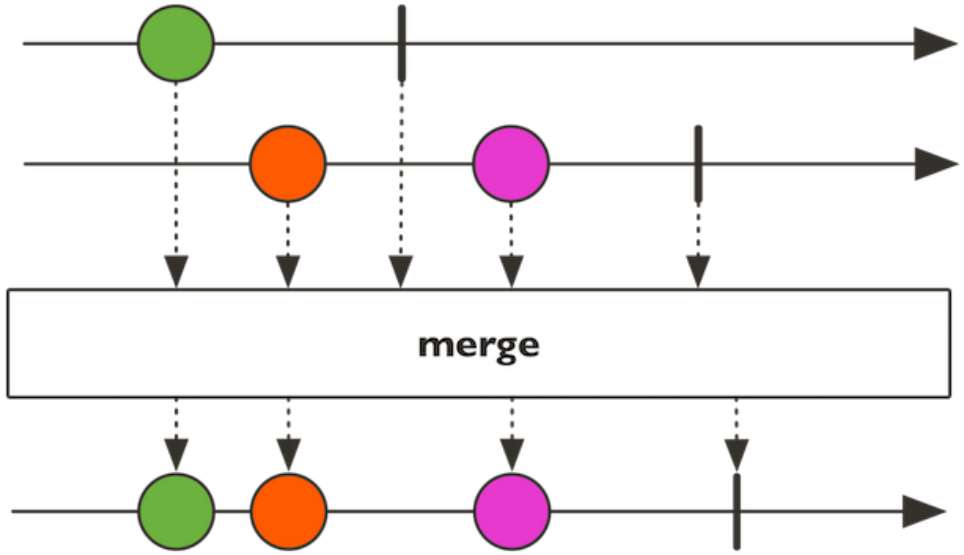
```
public Flux<Character> monoFlatMapIterable(int value){
     return Mono.just(value).flatMapIterable(val->{
                    List<Character> data=new ArrayList<>();
                    for(int i=0;i<val;i++){
                        char curr=(char)('a'+i);
                        data.add(curr);
                    }
                    return data;
              });
}
```

```
System.out.print("\n\nMono to Flux - Flat Map Iterable: \n");
ex.monoFlatMapIterable(5).subscribe(System.out::print);
```

```
Mono to Flux - Flat Map Iterable:
abcde
```

Mono to Flux

- Turning Mono into Flux:
  - mergeWith(Publisher<T> other)
    - merges <T> with given publisher
    - appends other to emitted <T>
    - returns Flux<T>



Mono to Flux

- Example:
  - mergeWith(…)

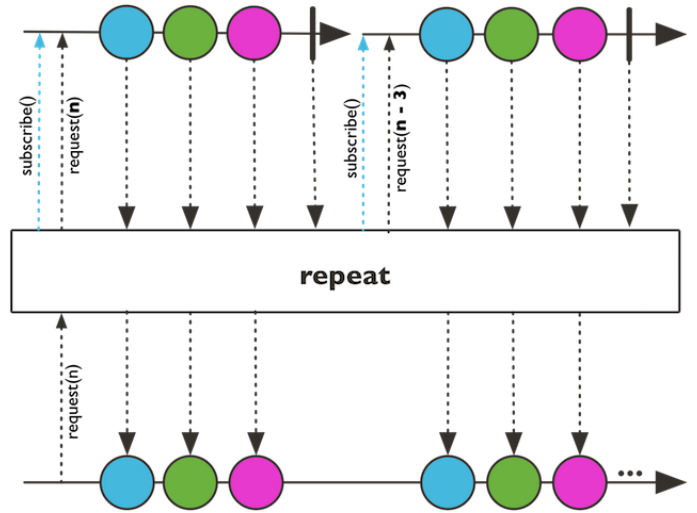
```
public Flux<String> monoMergeWith(){
     return Mono.just("Hello").mergeWith(Flux.just(" Reactive"," !!!"));
}
```

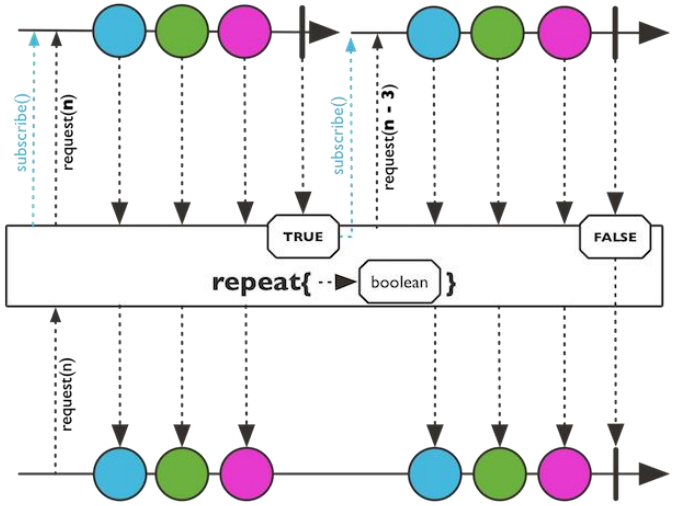
```
System.out.print("\n\nMono to Flux – Merge With: \n");
ex.monoMergeWith().subscribe(System.out::print);
```

```
Mono to Flux - Merge With:
Hello Reactive !!!
```

Mono to Flux

- Turning Mono into Flux:
  - repeat()
    - repeatedly & indefinitely subscribes current Mono<T>
    - keeps on subscribing endlessly on each completion
  - repeat(BooleanSupplier predicate)
    - does the same but stops when supplier returns ‘false’
  - repeat(long numOfRepeats)
    - does the same but stops after ‘numOfRepeats’ subscriptions
  - repeat(long numOfRepeats, BooleanSupplier predicate)





Mono to Flux

- Example:
  - repeat(…)

```
public Flux<String> monoRepeat(int numOfRepeats){
    return Mono.just("repeat ").repeat(numOfRepeats);
}
```

```
System.out.print("\n\nMono to Flux - Repeat: \n");
ex.monoRepeat(3).subscribe(System.out::print);
```

```
Mono to Flux - Repeat:
repeat repeat repeat
```

Mono to Flux

- Example:
  - repeat(…Predicate<T>)

```
public Flux<Integer> monoRepeatPredicate(int numOfRepeats){
     int value=(int)(Math.random()*10);
     System.out.print("("+value+") ");
     return Mono.just(value).repeat(numOfRepeats,()->value%2==0);
}
```

```
System.out.print("\n\nMono to Flux - Repeat Predicate: \n");
ex.monoRepeatPredicate(3).subscribe(System.out::print);
```

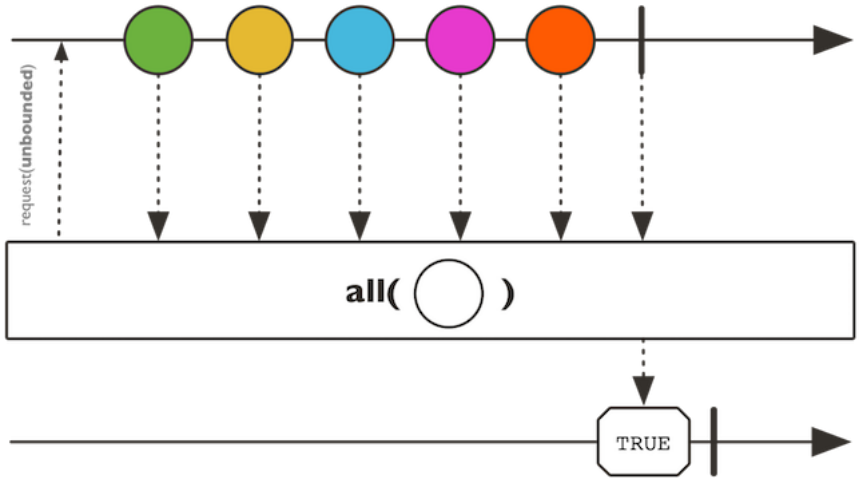
```
Mono to Flux - Repeat Predicate:
(3) 3
```

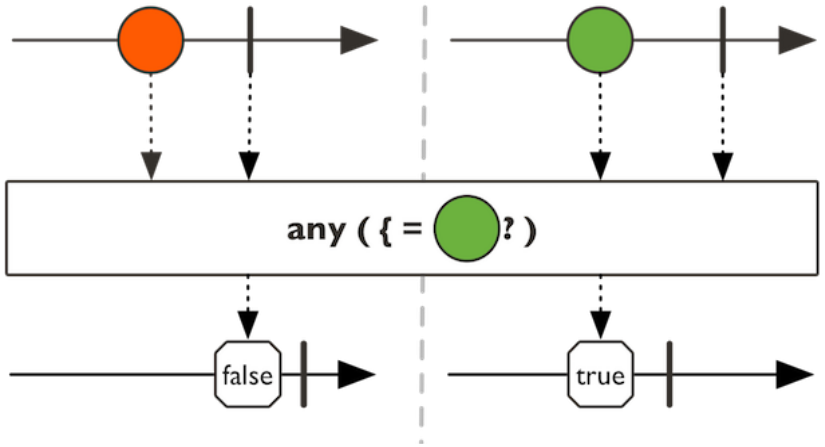
```
Mono to Flux - Repeat Predicate:
(8) 8888
```

Flux to Mono

Flux to Mono

- Turning Flux into Mono:
  - all(Predicate<T> test)
    - returns Mono<Boolean> with ‘true’ if all Flux values passes the test
  - any(Predicate<T> test)
    - returns Mono<Boolean> with ‘true’ if any of Flux values passes the test
  - Note: predicate takes a full Flux values array





Flux to Mono

- Example:
  - all(…)

```
public Mono<Boolean> fluxAll(Integer...numbers){
    return Flux.fromArray(numbers).all(num->num%2!=0);
}
```

```
System.out.print("\n\nFlux to Mono - All: \n");
ex.fluxAll(1,5,6).subscribe(System.out::print);
```

```
Flux to Mono - All:
false
```

Flux to Mono

- Example:
  - any(…)

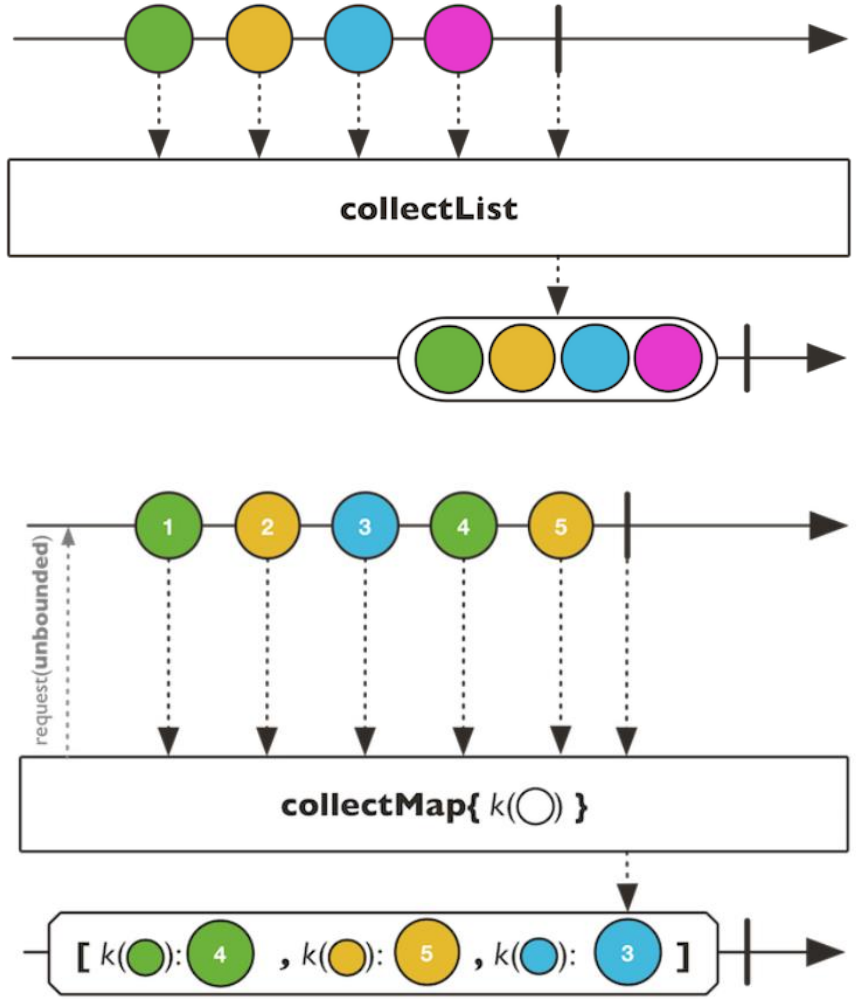
```
public Mono<Boolean> fluxAny(Integer...numbers){
    return Flux.fromArray(numbers).any(num->num%2!=0);
}
```

```
System.out.print("\n\nFlux to Mono - Any: \n");
ex.fluxAny(1,4,5).subscribe(System.out::print);
```

```
Flux to Mono - Any:
true
```

Flux to Mono

- Turning Flux into Mono:
  - collectList()
    - returns Mono<List<T>> containing all Flux<T> values when the sequence completes
  - collectMap(Function<T,K> extractor)
    - returns Mono<Map<K,T>> containing all Flux<T> values when the sequence completes
    - each T value is attached to a Key <K> extracted via given Function<T,K>



Flux to Mono

- Example:
  - collectList(…)

```
public Mono<List<Integer>> fluxCollectList(Integer...numbers){
   return Flux.fromArray(numbers).collectList();
}
```

```
System.out.print("\n\nFlux to Mono - Collect List: \n");
ex.fluxCollectList(1,2,3).subscribe(System.out::print);
```

```
Flux to Mono - Collect List:
[1, 2, 3]
```

Flux to Mono

- Example:
  - collectList(…)

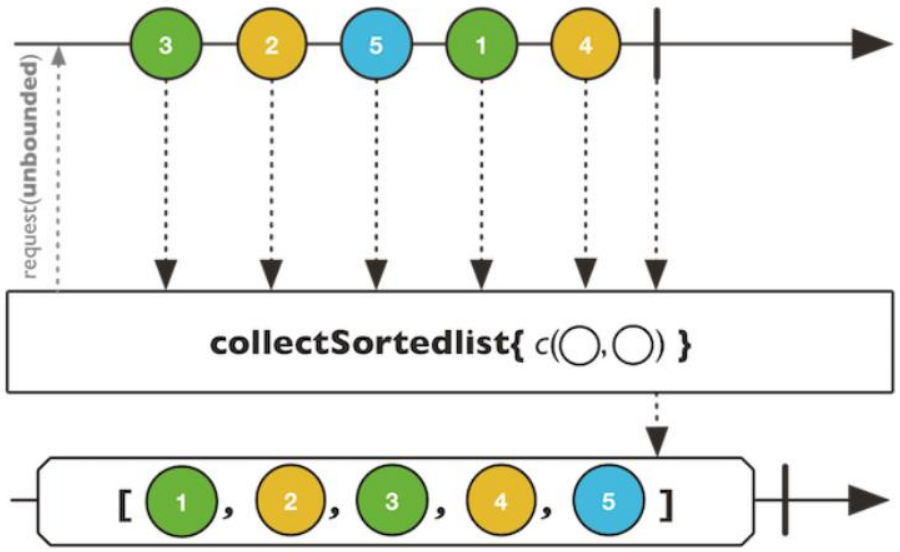
```
public Mono<Map<Integer,String>> fluxCollectMap(String ...values){
    return Flux.fromArray(values).collectMap(str->str.length());
}
```

```
System.out.print("\n\nFlux to Mono - Collect Map: \n");
ex.fluxCollectMap("a","bbb","cc").subscribe(System.out::print);
```

```
Flux to Mono - Collect Map:
{1=a, 3=bb, 2=ccc}
```

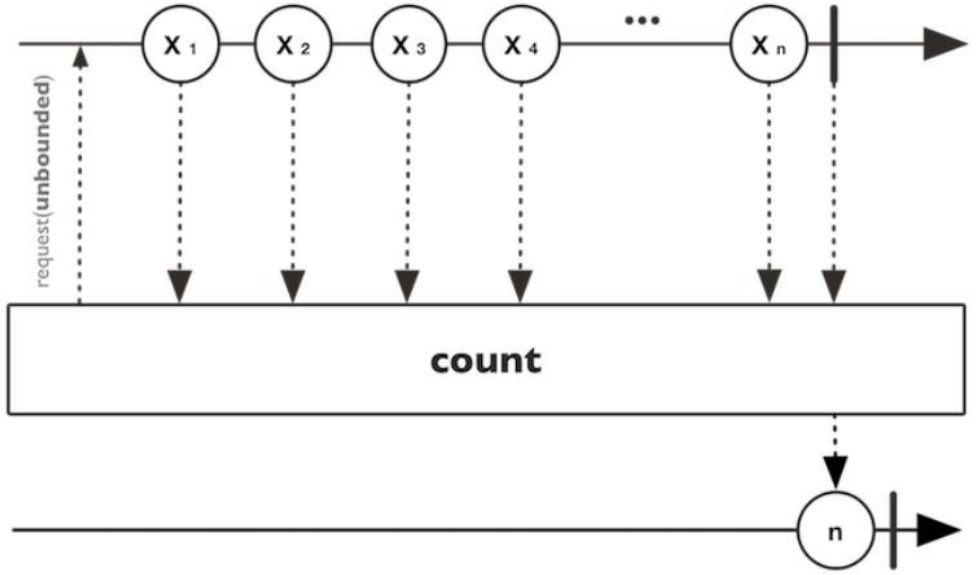
Flux to Mono

- Turning Flux into Mono:
  - collectSortedList()
  - collectSortedList(Comparator<T> comparator)
    - returns Mono<List<T>> containing all Flux<T> values when the sequence completes
    - List<T> is sorted according to natural ordering or given Comparator<T>



Flux to Mono

- Turning Flux into Mono:
  - count()
    - results in Mono<Long> which describes the number of values in current Flux<T>



Flux to Mono

- Example:
  - count(…)

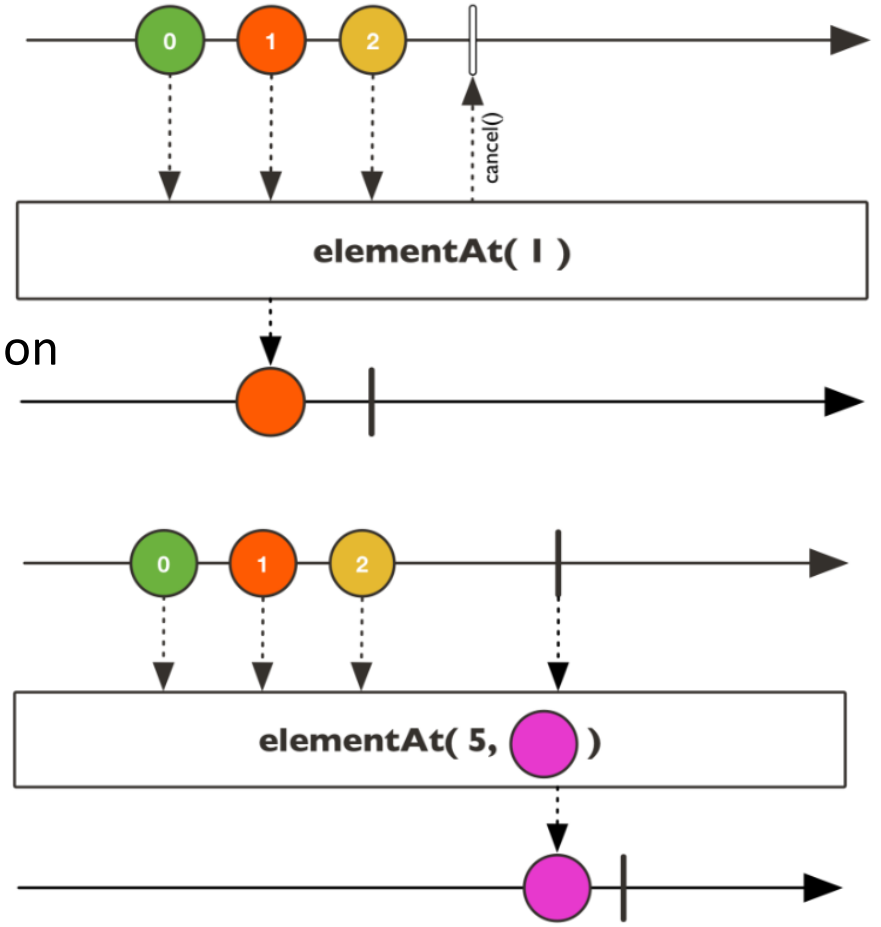
```
public Mono<Long> fluxCount(String...values){
   return Flux.fromArray(values).count();
}
```

```
System.out.print("\n\nFlux to Mono - Count: \n");
ex.fluxCount("a","bb","ccc").subscribe(System.out::print);
```

```
Flux to Mono - Count:
3
```

Flux to Mono

- Turning Flux into Mono:
  - elementAt(int position)
    - emits only the value in the given position
    - If no such position – throws IndexOutOfBoundsException
  - elementAt(int position, T defaultValue)
    - emits only the value in the given position
    - If no such position – returns ‘defaultValue’



Flux to Mono

- Example:
  - elementAt(…)

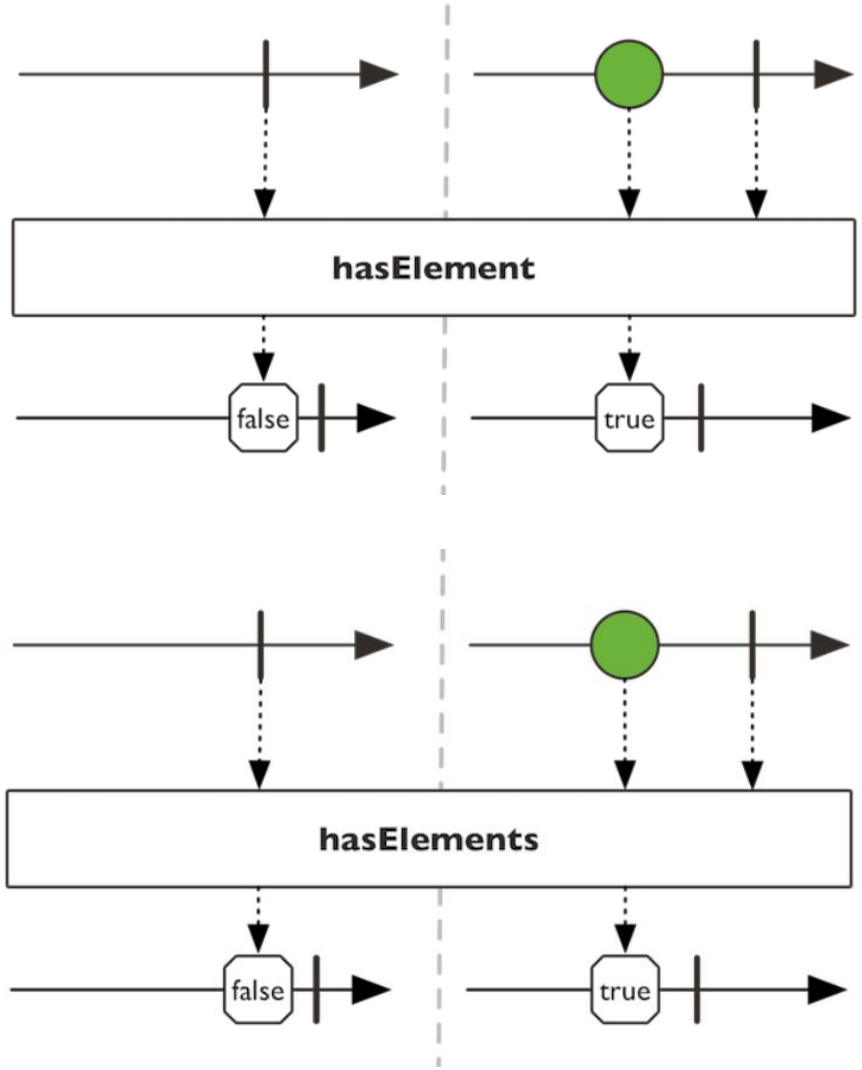
```
public Mono<String> fluxElementAt(int position){
   return fluxFrom().elementAt(position,"Not Found");
}
```

```
System.out.print("\n\nFlux to Mono - Element At: \n");
ex.fluxElementAt(2).subscribe(System.out::print);
```

```
Flux to Mono - Element At:
ccc
```

Flux to Mono

- Turning Flux into Mono:
  - hasElement(T value)
    - returns Mono<Boolean> with ‘true’ if any of the Flux values equals to ‘value’
  - hasElements()
    - returns Mono<Boolean> with ‘true’ if Flux is not empty



Flux to Mono

- Example:
  - hasElement(…)

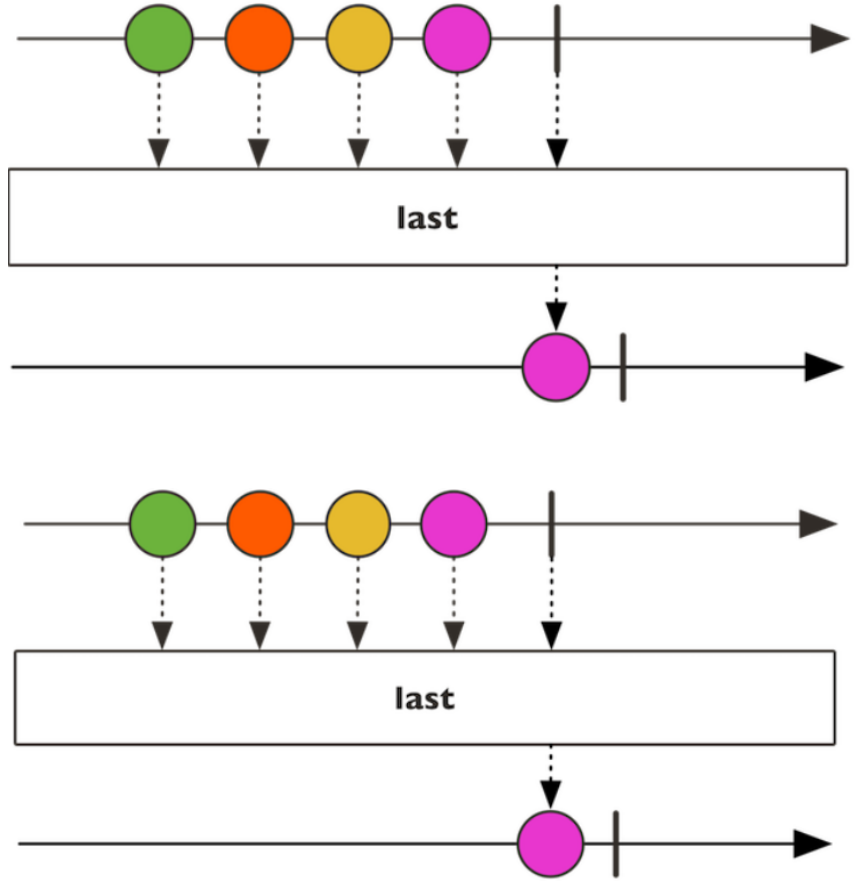
```
public Mono<Boolean> fluxHasElement(String value){
   return fluxFrom().hasElement(value);
}
```

```
System.out.print("\n\nFlux to Mono - Has Element: \n");
ex.fluxHasElement("zzz").subscribe(System.out::print);
```

```
Flux to Mono - Has Element:
false
```

Flux to Mono

- Turning Flux into Mono:
  - last()
    - emits last value of the current Flux<T>
    - if empty – throws NoSuchElementException
  - last(T defaultValue)
    - emits last value of the current Flux<T>
    - If empty – returns ‘defaultValue’



Flux to Mono

- Example:
  - last(…)

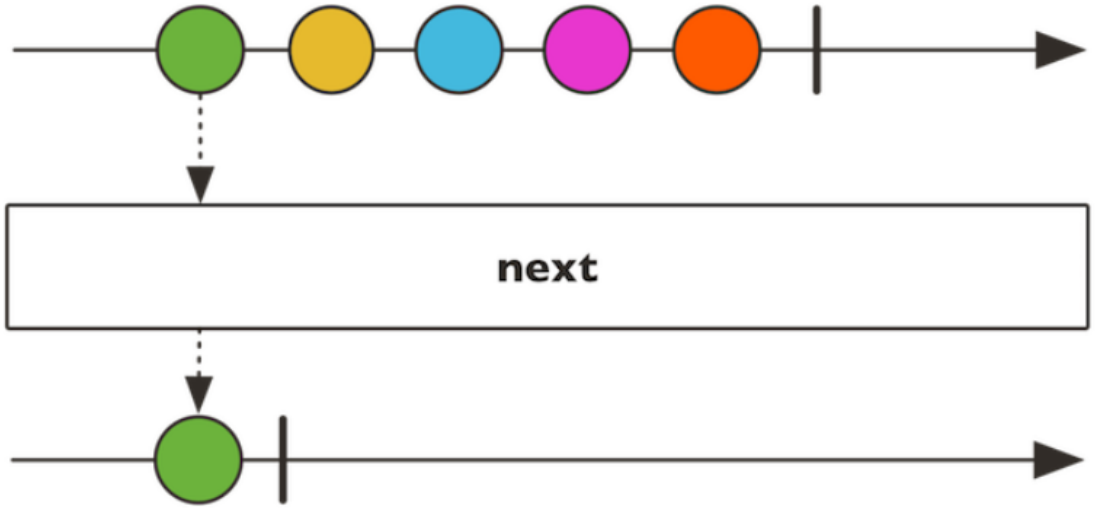
```
public Mono<String> fluxLast(){
   return fluxFrom().last();
}
```

```
System.out.print("\n\nFlux to Mono - Last: \n");
ex.fluxLast().subscribe(System.out::print);
```

```
Flux to Mono - Last:
ccc
```

Flux to Mono

- Turning Flux into Mono:
  - next()
    - emits the next value of the current Flux<T>
    - if Flux<T> is empty – returns empty Mono<?>



Flux to Mono

- Example:
  - next(…)

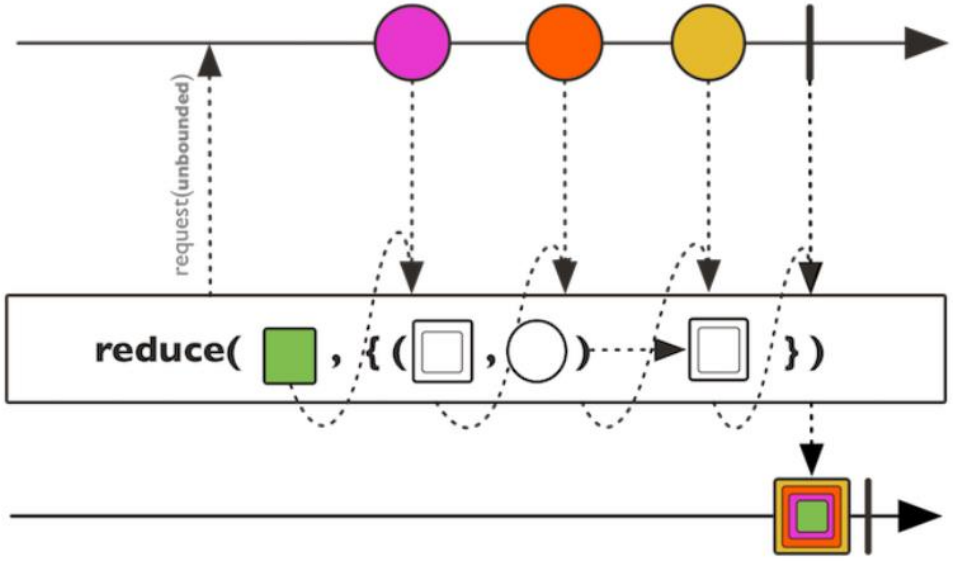
```
public Mono<String> fluxNext(){
   return fluxFrom().next();
}
```

```
System.out.print("\n\nFlux to Mono - Next: \n");
ex.fluxNext().subscribe(System.out::print);
```

```
Flux to Mono - Next:
aaa
```

Flux to Mono

- Turning Flux into Mono:
  - reduce(A initial, BiFunction<A,T,A> reducer)
  - reduceWith(Supplier<A> initial, BiFunction<A,T,A> reducer)
    - reduces all <T> values into <A> single value
    - starts with given initial value / supplier
    - uses BiFunction<A,T,A> which merges each T into given A and results with A value
  - reduce(BiFunction<T,T,T> aggregator)
    - reduces all <T> values into <T> single value
    - uses BiFunction<T,T,T> which merges each T into given T and results with T value
    - starts with the first value of current Flux<T>



Flux to Mono

- Example:
  - reduce(…)

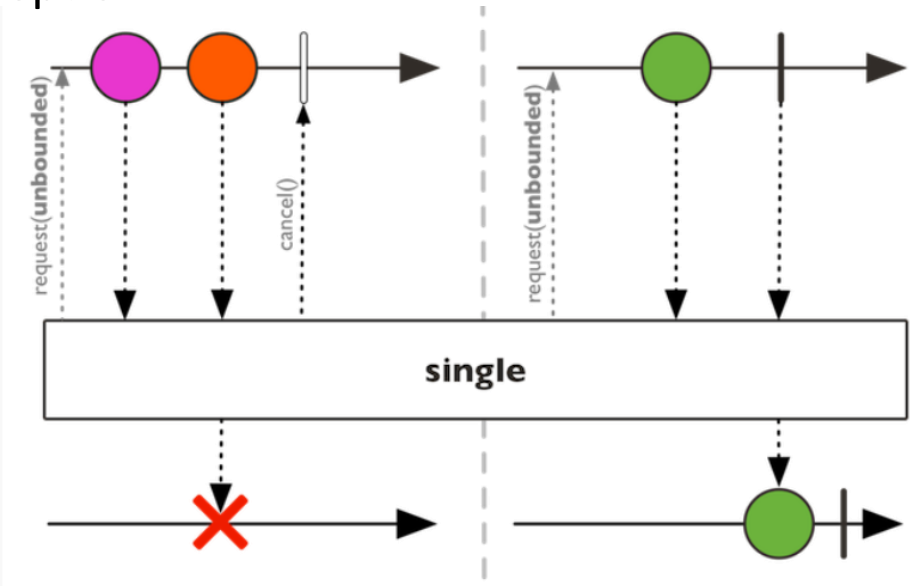
```
public Mono<Integer> fluxReduce(String...values){
    return Flux.fromArray(values).reduce(0,(result,value)->result+=value.length());
}
```

```
System.out.print("\n\nFlux to Mono - Reduce: \n");
ex.fluxReduce("a","bb","ccc").subscribe(System.out::print);
```

```
Flux to Mono - Reduce:
6
```

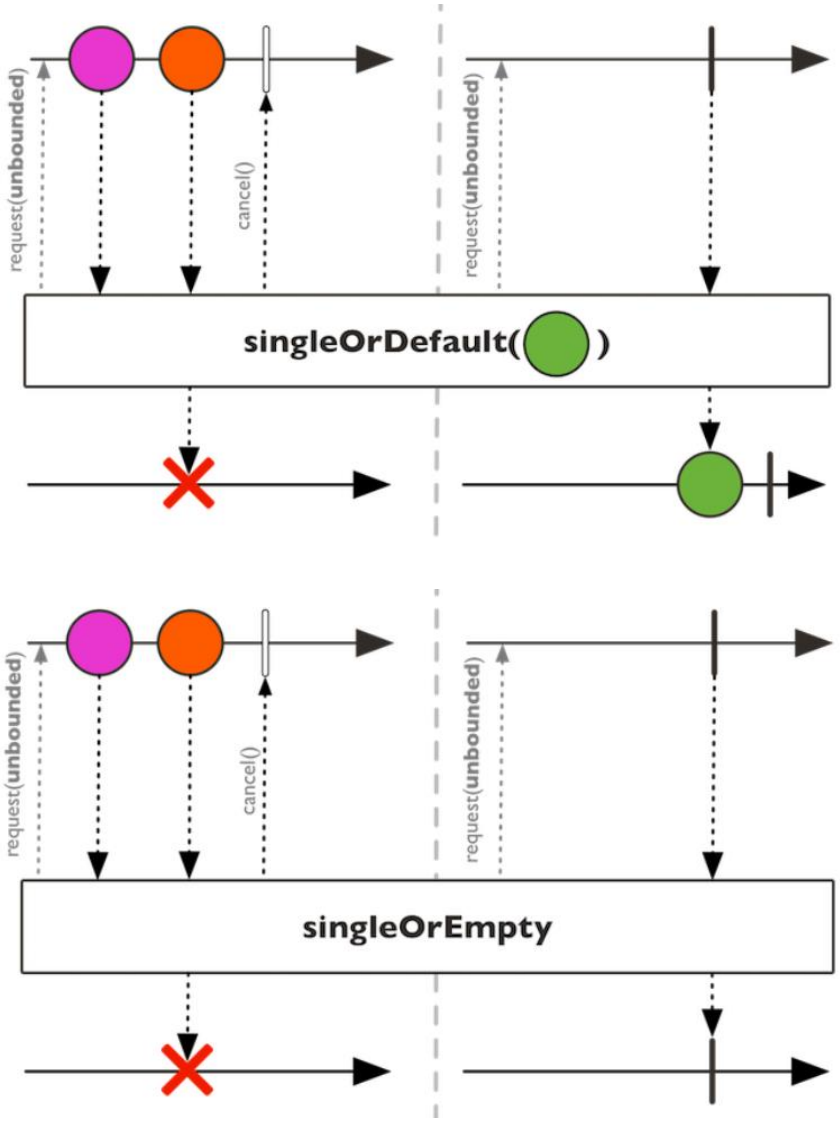
Flux to Mono

- Turning Flux into Mono:
  - single()
    - emits the single value of the current Flux<T>
    - if Flux<T> is empty – throws IndexOutOfBoundsException
    - If Flux<T> has more than one element – throws NoSuchElementException



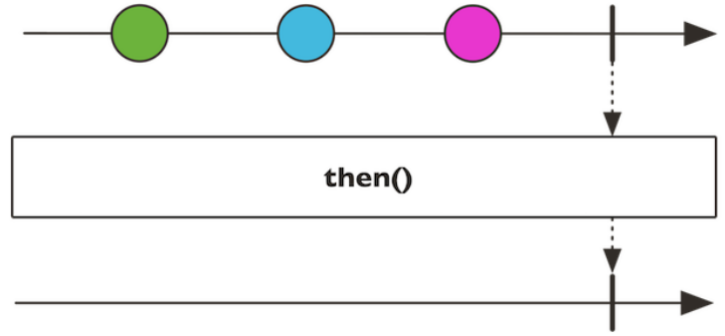
Flux to Mono

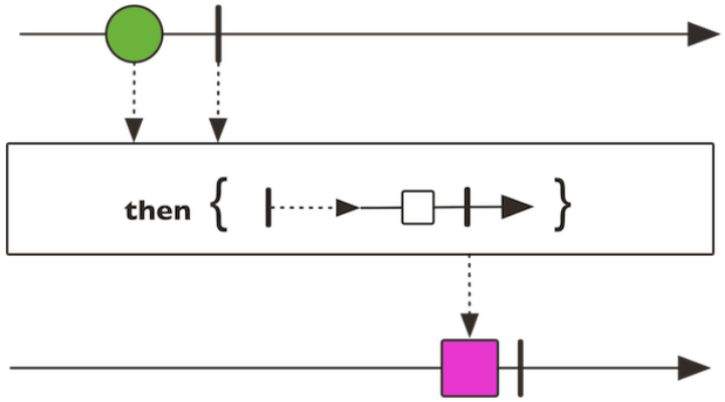
- Turning Flux into Mono:
  - single(T defaultValue)
    - emits the single value of the current Flux<T>
    - if Flux<T> is empty – returns ‘defaultValue’
    - If Flux<T> has more than one element – throws NoSuchElementException
  - singleOrEmpty()
    - emits the single value of the current Flux<T>
    - if Flux<T> is empty – returns empty Mono<?>
    - If Flux<T> has more than one element – throws NoSuchElementException



Flux to Mono

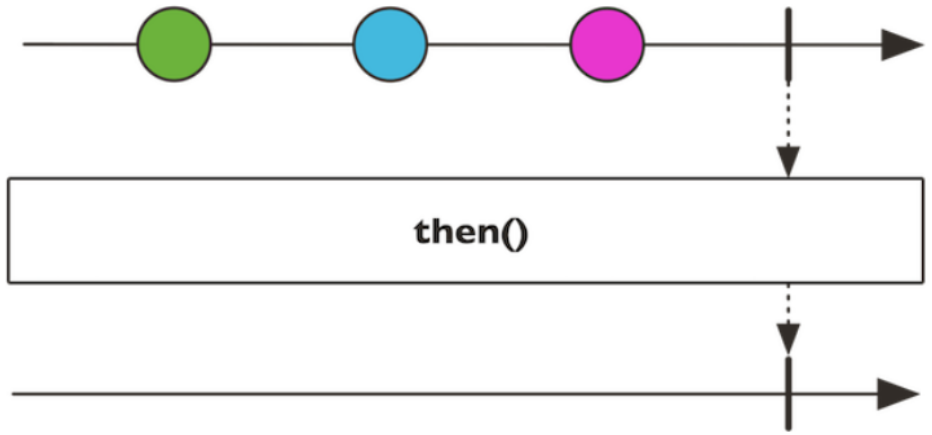
- Turning Flux into Mono:
  - then()
    - returns Mono<Void> which signals when current Flux<T> completes
  - then(Mono<V> other)
    - plays signals from given Mono<V> when current Flux<T> completes





Flux to Mono

- Turning Flux into Mono:
  - thenEmpty(Publisher<Void> other)
    - Returns Mono<Void> which signals after both current Flux<T> and given Publisher<Void> ‘other’ completes



Flux to Mono

- Example:
  - then(…)

```
public Mono<String> fluxThen(){
   return Flux.just(1,2,3,4,5).doOnNext(System.out::print).then(Mono.just(" Done"));
}
```

```
System.out.print("\n\nFlux to Mono - Then: \n");
ex.fluxThen().subscribe(System.out::print);
```

```
Flux to Mono - Then:
12345 Done
```

Flux & Mono Logging

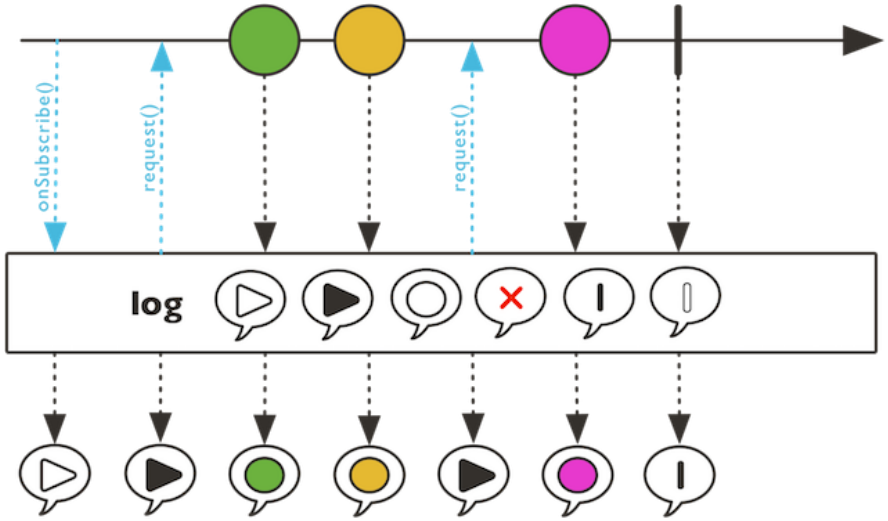
- Logging all subscription activity
  - log()
    - observes all reactive stream signals
    - uses Logger which can be set to categorized logging
    - Logger is set to INFO level
    - Log message format:

      <date> <level> <thread> reactor.Flux.<Impl>.<count> <event>

      - thread – is the running thread name

      - Impl – is the actual Flux inner implementation – mostly Map

      - count – is the serial number of the inner implementation instance



  - log(Logger logger, Level level, SignalType…signalTypes)

```
flux.log(myCustomLogger, Level.INFO, SignalType.ON_NEXT, SignalType.ON_ERROR)
```

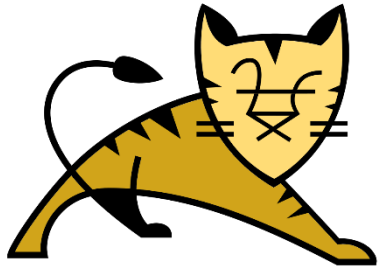
Spring WebFlux

Spring WebFlux

- Uses HTTP2 communication and data streaming
- Reactive web is not for executing faster
- Reactive web is for scaling with a limited number of threads
- WebFlux uses fixed-size thread pool (event loop workers) to handle requests
  - default size is available processors
- All SpringMVC forms & REST annotations are valid and relevant

Spring WebFlux

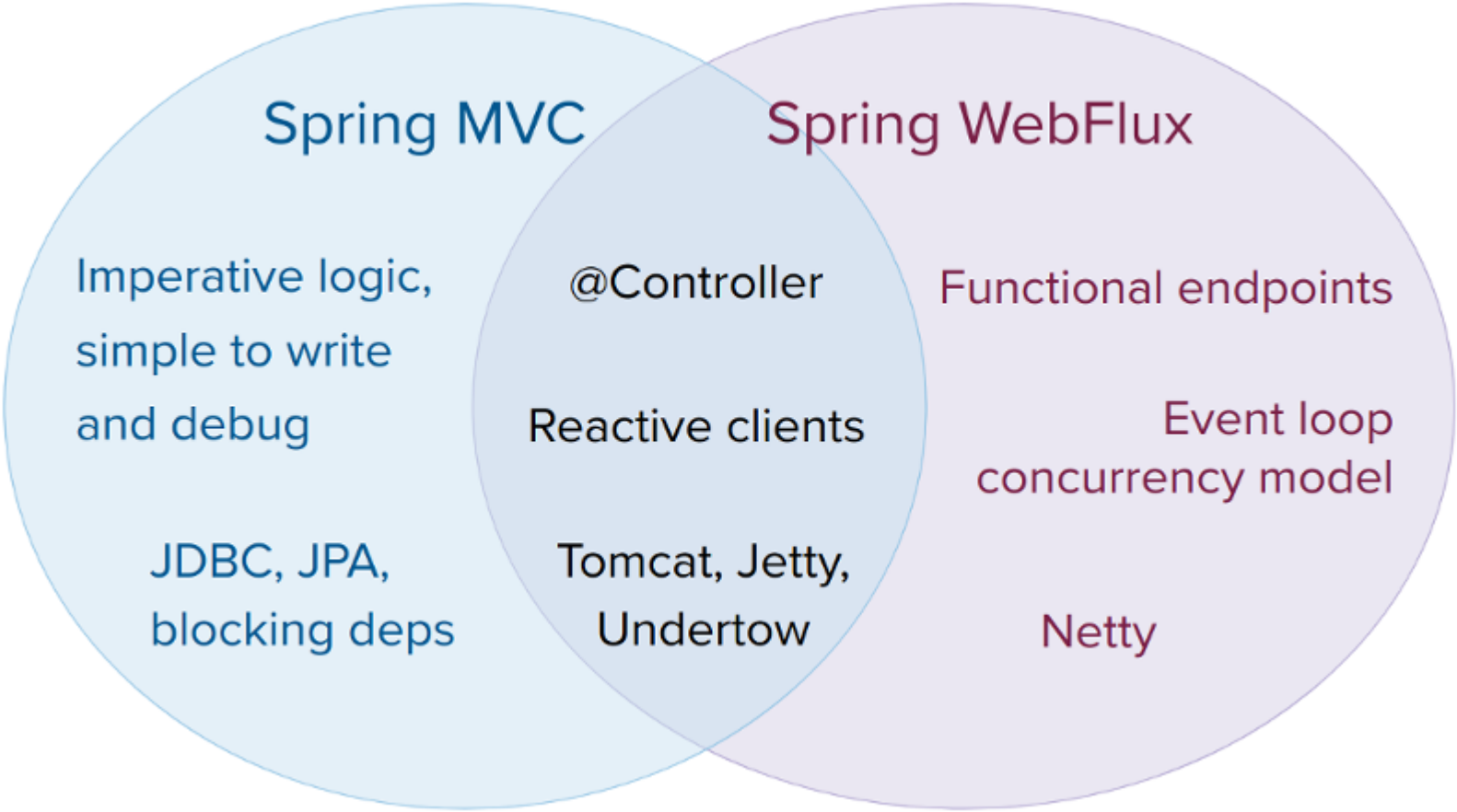
- Supported servers:
  - Netty (default)
  - Tomcat
  - Jetty



  - Tomcat & Jetty
    - are based on Servlet API
    - relevant when using both SpringMVC & WebFlux
    - WebFlux uses low-level Servlet TCP communication for streaming
    - must support Servlet 3.1 (NIO)

Spring WebFlux

- SpringMVC / Spring WebFlux



Spring WebFlux

- Configuration
  - Maven dependency
    - Includes embedded Netty

```
<dependency>
        <groupId>org.springframework.boot</groupId>
        <artifactId>spring-boot-starter-webflux</artifactId>
</dependency>
```

  - Spring property `spring.main.web-application-type` is set to ‘reactive’ by default
    - Set the web engine to be reactive
    - Disabling Spring-MVC is a must!

```
spring.main.web-application-type=reactive
```

Spring WebFlux

- Reactive Controller
  - also denoted with @RestController
  - returns Mono<T> & Flux<T> instead of T or ResponseEntity<?>
  - uses HTTP2 STREAM capable MIME types
    - TEXT_EVENT_STREAM_VALUE – for plain text & JSONS
    - APPLICATION_OCTET_STREAM_VALUE – for binary streams

Spring WebFlux

- Reactive Controller Example:

```
@RestController
public class ReactiveController{


   @GetMapping(value="item", produces=MediaType.TEXT_EVENT_STREAM_VALUE)
   public Mono<Item> item(){
        …..
   }

   @GetMapping(value="items", produces=MediaType.TEXT_EVENT_STREAM_VALUE)
   public Flux<Item> items(){
        …..
   }
}
```

```
public class Item {

   private long id;
   private String name;

   public long getId() {
     return id;
   }
   public void setId(long id) {
     this.id = id;
   }
   public String getName() {
     return name;
   }
   public void setName(String name) {
     this.name = name;
   }
}
```

Spring WebFlux

- JSON streaming results differently:
  - MediaType.APPLICATION_JSON :
    - browser blocks until response load completes EVEN when resulting with Mono<T> or Flux<T>
    - Mono & Flux doesn’t effect

```
[{"id":1,"name":"item1"},{"id":2,"name":"item2"},{"id":3,"name":"item3"}]
```

  - MediaType.TEXT_EVENT_STREAM_VALUE :
    - browser uses streaming for Mono & Flux
    - Each stream emitted item gets ‘data: ……..’

```
data:{"id":1,"name":"item1"}
```

```
data:{"id":1,"name":"item1"}

data:{"id":2,"name":"item2"}

data:{"id":3,"name":"item3"}
```

Spring WebFlux

- JSON streaming results differently:
  - MediaType.TEXT_EVENT_STREAM_VALUE :
    - Same goes for simple types and primitives

```
data: 1

data: 2

data: 3
```

```
data: item1

data: item2

data: item3
```

Spring WebFlux

- block(), blockFirst(), blockLast() not supported for http streaming
  - these methods forces a thread to wait for outcomes
  - It is totally unwanted when
    - using limited number of threads
    - computation might take time
  - Spring WebFlux will throw IllegalStateException in such cases

```
java.lang.IllegalStateException: block()/blockFirst()/blockLast() are blocking,
which is not supported in thread reactor-http-nio-2
```

Spring WebFlux

- WebFlux reactor distributes events to handlers (‘ctor-http-nio’)
- This can be shown via logging web stream activity (*log()*)
- Example of handling http request for Flux<Value>:

```
INFO 23052 --- [main] o.s.b.web.embedded.netty.NettyWebServer : Netty started on port(s): 8080
INFO 23052 --- [main] react.Application : Started Application in 5.172 seconds (JVM running for 5.85)
INFO 23052 --- [ctor-http-nio-1] reactor.Flux.TakeUntil.1 : onSubscribe(TakeUntilPredicateSubscriber)
INFO 23052 --- [ctor-http-nio-1] reactor.Flux.TakeUntil.1 : request(32)
INFO 23052 --- [ctor-http-nio-1] reactor.Flux.TakeUntil.1 : onNext(react.web.Value@23f3a0b3)
INFO 23052 --- [ctor-http-nio-1] reactor.Flux.TakeUntil.1 : onNext(react.web.Value@6f394543)
INFO 23052 --- [ctor-http-nio-1] reactor.Flux.TakeUntil.1 : onNext(react.web.Value@1c6ca1f6)
INFO 23052 --- [ctor-http-nio-1] reactor.Flux.TakeUntil.1 : onNext(react.web.Value@7780fdb5)
INFO 23052 --- [ctor-http-nio-1] reactor.Flux.TakeUntil.1 : onNext(react.web.Value@49c83dce)
INFO 23052 --- [ctor-http-nio-1] reactor.Flux.TakeUntil.1 : onNext(react.web.Value@6cfe6ae9)
INFO 23052 --- [ctor-http-nio-1] reactor.Flux.TakeUntil.1 : onComplete()
```

Parallel Mono/Flux

Parallel Flux/Mono

- Usually, subscriber thread is used to consume values from Flux/Mono
- If needed, streams may be handled with separate thread/s
- This can be done in 2 ways
  - Specify different workers to handle stream
  - Turn Flux<T> into ParallelFlux<T>
    - publishes to an array of Subscribers, in parallel 'rails' (or 'groups')
  - Scheduler objects helps in specifying workers

Parallel Flux/Mono

- Scheduler – asynchronous stream handler
- Schedulers – factors scheduler objects:
  - fromExecutorService(ExecutorService)
    - uses given executor to handle stream
  - parallel()
  - newParallel(String poolName)
    - instantiates & uses fixed pool of single-threaded executor-services - parallel capable
  - newParallel(String poolName, int parallelism)
  - newParallel(String poolName, int parallelism, Boolean daemon)
    - does the same but with given name & number of executor-services – parallel capable
  - newSingle(String poolName)
  - newSingle(String poolName, Boolean daemon)
  - newSingle(ThreadFactory factory)
    - instantiates & uses fixed pool of single-threaded executor-services – parallel capable

Parallel Flux/Mono

- Example:
  - Schedulers.newParallel(…) – handling elements with separate thread

```
public void handlingElementsInSeperateThread() {
   Flux.just("yellow","red", "white", "blue")
       .subscribeOn(Schedulers.parallel())
       .map(String::toUpperCase)
       .log().subscribe();
}
```

```
System.out.print("\n\nParallel: Handling all elements in seperate thread: \n");
pex.handlingElementsInSeperateThread();
```

```
Parallel: Handling all elements in seperate thread:
INFO 21096 --- [ main] reactor.Flux.Map.1 : onSubscribe(FluxMap.MapSubscriber)
INFO 21096 --- [ main] reactor.Flux.Map.1 : request(unbounded)
INFO 21096 --- [ parallel-1] reactor.Flux.Map.1 : onNext(YELLOW)
INFO 21096 --- [ parallel-1] reactor.Flux.Map.1 : onNext(RED)
INFO 21096 --- [ parallel-1] reactor.Flux.Map.1 : onNext(WHITE)
INFO 21096 --- [ parallel-1] reactor.Flux.Map.1 : onNext(BLUE)
INFO 21096 --- [ parallel-1] reactor.Flux.Map.1 : onComplete()
```

Parallel Flux/Mono

- Example:
  - Schedulers.newParallel(…) – handling each element with available thread

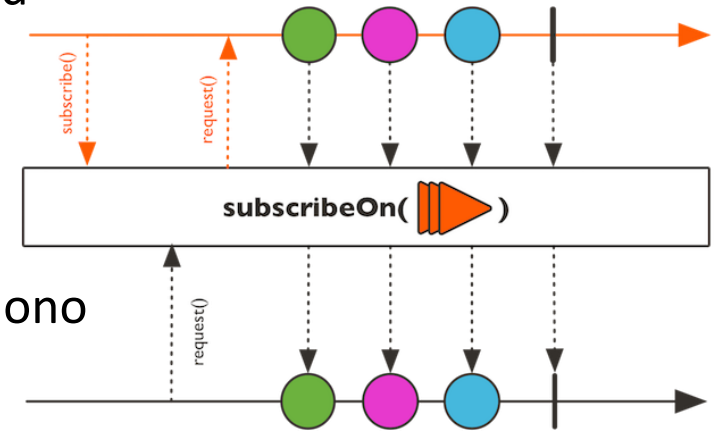
```
public void handlingEachElementInSeperateThread() {
    Flux.just("yellow","red", "white", "blue")
        .flatMap(s->Mono.just(s)
        .subscribeOn(Schedulers.parallel()).delayElement(Duration.ofSeconds((int)(Math.random()*4))))
        .map(String::toUpperCase)
        .log().subscribe();
}
```

```
System.out.print("\n\nParallel: Handling each element in separate thread: \n");
pex.handlingEachElementInSeparateThread();
```

```
Parallel: Handling each element in seperate thread:
INFO 21096 --- [ main] reactor.Flux.Map.2 : onSubscribe(FluxMap.MapSubscriber)
INFO 21096 --- [ main] reactor.Flux.Map.2 : request(unbounded)
INFO 21096 --- [ parallel-1] reactor.Flux.Map.2 : onNext(YELLOW)
INFO 21096 --- [ parallel-1] reactor.Flux.Map.2 : onNext(WHITE)
INFO 21096 --- [ parallel-2] reactor.Flux.Map.2 : onNext(BLUE)
INFO 21096 --- [ parallel-2] reactor.Flux.Map.2 : onNext(RED)
INFO 21096 --- [ parallel-2] reactor.Flux.Map.2 : onComplete()
```

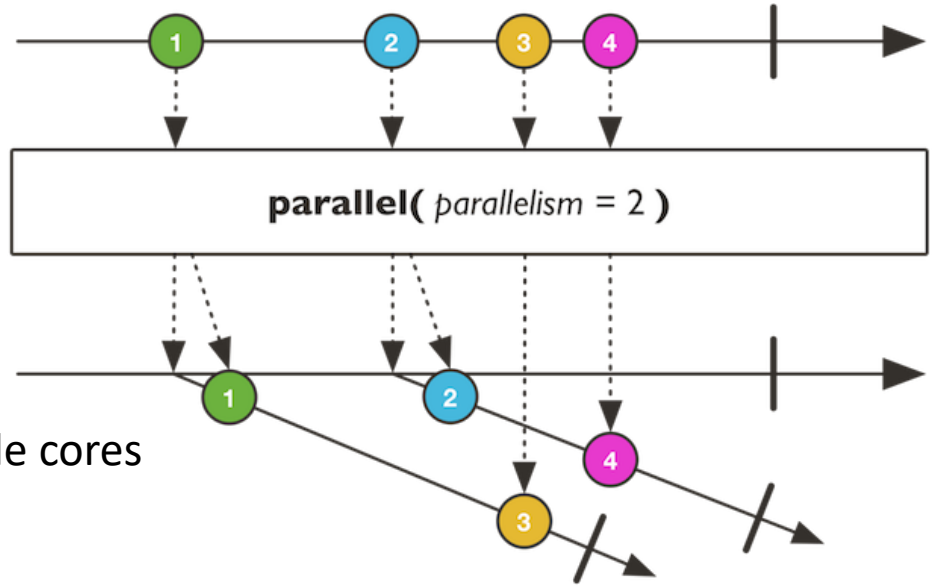
Parallel Flux

- Setting Flux/Mono with workers
  - Forking stream element processing:
    - This is done via subscribeOn(Scheduler asynchHandler) method
  - Forking each element handling in a stream
    - For this we map Flux<T> into Flux<Mono<T>> and fork each Mono
    - Or use built-in Flux parallel mechanism



Parallel Flux

- Flux<T> into ParallelFlux<T>
  - parallel()
  - parallel (int parallelism)
  - parallel(int parallelism, int prefetch)
    - Prepares ParallelFlux<T> from current Flux<T>
      - default number of workers is set according to available cores
      - specify number of workers via ‘parallelism’
      - mechanism is round-robin-based
      - ‘prefetch’ sets the max amount of values for each worker at a time
    - Caller thread is used to dispatch work
  - Must use ParallelFlux.runOn(Scheduler schedule) to enable parallel subscription



Parallel Flux

- Example:
  - parallel(…)

```
public void parallelFlux() {
         Flux.just("yellow","red", "white", "blue")
             .parallel(2)
             .map(String::toUpperCase)
             .runOn(Schedulers.parallel())
             .log().subscribe();
}
```

```
System.out.print("\n\nParallel: ParallelFlux: \n");
pex.parallelFlux();
```

```
Parallel: ParallelFlux:
INFO 22704 --- [ main] reactor.Parallel.RunOn.3 : onSubscribe([Fuseable]
INFO 22704 --- [ main] reactor.Parallel.RunOn.3 : request(unbounded)
INFO 22704 --- [ main] reactor.Parallel.RunOn.3 : onSubscribe([Fuseable]
INFO 22704 --- [ main] reactor.Parallel.RunOn.3 : request(unbounded)
INFO 22704 --- [ parallel-1] reactor.Parallel.RunOn.3 : onNext(YELLOW)
INFO 22704 --- [ parallel-2] reactor.Parallel.RunOn.3 : onNext(RED)
INFO 22704 --- [ parallel-1] reactor.Parallel.RunOn.3 : onNext(WHITE)
INFO 22704 --- [ parallel-2] reactor.Parallel.RunOn.3 : onNext(BLUE)
INFO 22704 --- [ parallel-1] reactor.Parallel.RunOn.3 : onComplete()
INFO 22704 --- [ parallel-2] reactor.Parallel.RunOn.3 : onComplete()
```

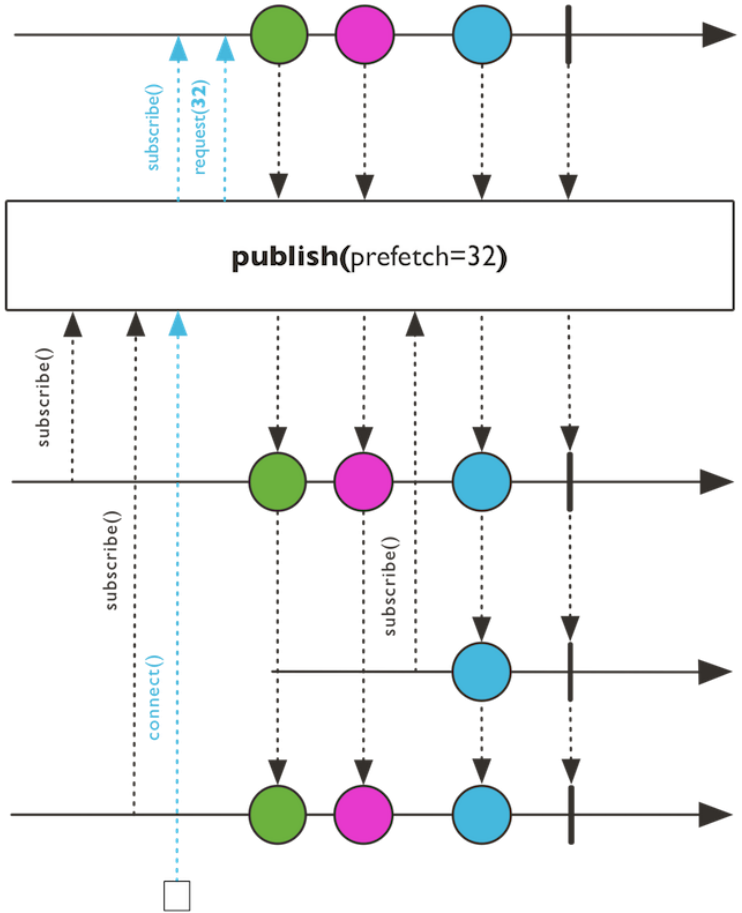
Connectable Flux

Connectable Flux

- Connectable Flux provides the following capabilities:
  - Join upstream during on-going subscription – Hot Stream
    - Cold Streams – which are the default, forces subscribers to take from the beginning of the stream
    - Hot Streams – once connected, allows subscribers to join at any time while streaming data
  - Delay on-going subscription until minimum number of subscribers performs
  - Turn a whole Flux<T> or parts of it into hot streams - replaying

Connectable Flux

- Flux<T> can be transformed into ConnectableFlux<T>
  - publish()
  - publish(int prefetch)
    - returns ConnectableFlux<T>
    - connectable Flux is not ‘turned-on’ yet
    - time to connect…
  - NOTE: Connectable Flux are parallel capable



Connectable Flux

- ConnectableFlux<T> must connect upstream in order to provide Flux<T>
  - autoConnect()
  - autoConnect(int minSubscribers)
    - automatically connects upstream when specified amount of ‘minSubscribers’ subscribes
  - connect()
    - automatically connects upstream
  - refCount()
  - refCount(int minSubscribers)
    - automatically connects upstream after specified amount of ‘minSubscribers’ and disconnects after all subscribers canceled or completed

Connectable Flux

- Example:
  - publish(…) & connect

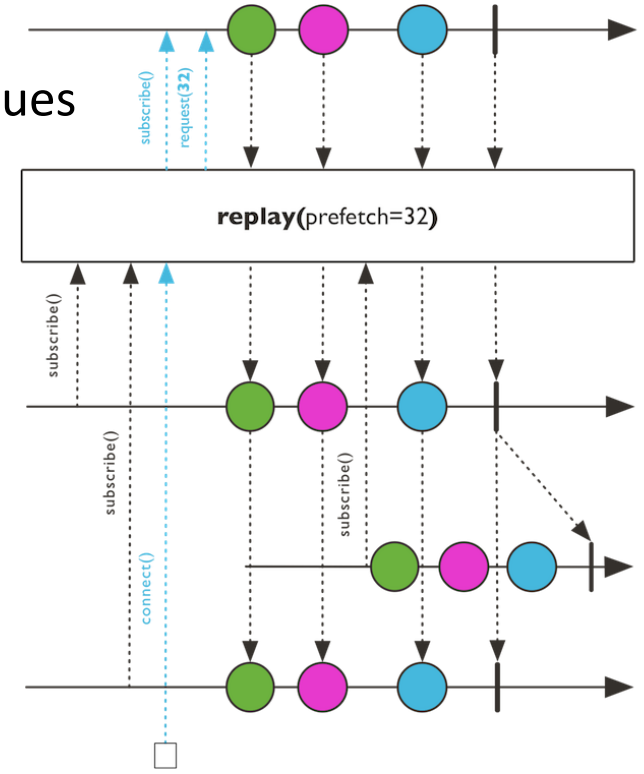
```
public void connectableExample() {
    Flux<String> source = Flux.just("aaa", "bbb", "ccc", "ddd","eee","fff")
                              .delayElements(Duration.ofSeconds(1))
                              .doOnNext(System.out::println)
                             .map(String::toUpperCase);
    ConnectableFlux<String> connectable = source.publish();
    //subscription is now enabled
    connectable.connect();
     //start with single subscriber
    connectable.subscribe(d -> System.out.println("Subscriber 1: "+d));
    //delay before adding subscriber
    try {Thread.sleep(2000);}catch(Exception e) {}
    //join with another subscriber
    connectable.subscribe(d -> System.out.println("Subscriber 2: "+d));
}
```

```
System.out.print("\n\nConnectable: ConnectableFlux: \n");
cex.connectableExample();
```

```
Connectable: ConnectableFlux:
aaa
Subscriber 1: AAA
bbb
Subscriber 1: BBB
Subscriber 2: BBB
ccc
Subscriber 1: CCC
Subscriber 2: CCC
ddd
Subscriber 1: DDD
Subscriber 2: DDD
eee
Subscriber 1: EEE
Subscriber 2: EEE
fff
Subscriber 1: FFF
Subscriber 2: FFF
```

Connectable Flux

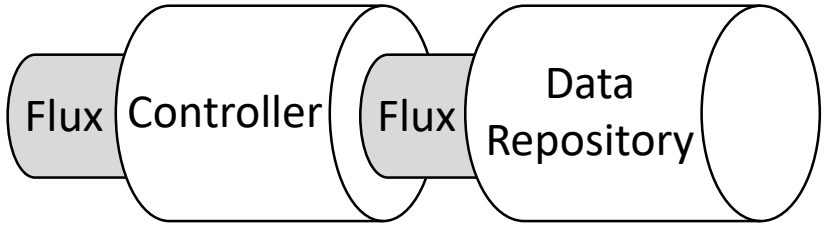
- Turning parts of Flux<T> into ConnectableFlux<T>
  - replay()
    - returns ConnectableFlux which contains all further subscribed values
    - grows infinitely
    - complete and error terminations are also streamed
  - replay(int history)
  - replay(Duration ttl)
    - same but keeps some history
    - history – holds specified amount of latest subscribed values
    - ttl - holds latest subscribed values according to Time-To-Live



Reactive Repository with MongoDB

Reactive Repository with MongoDB

- Reactive supported DBs provides a Reactor mechanism as well
  - DB Server plays the role of the Reactor
  - The reactor distributes events to Connections which are the handlers
  - Connections uses different thread resources to prevent reactor blocking



- Spring reactive repository
  - ReactiveCrudRepository interface
  - Results with Mono<T> & Flux<T> instead of T & List<T>
  - Implements Reactor DP, uses reactive driver implementation

Reactive Repository with MongoDB

- MongoDB
  - DB server may be standalone or embedded
  - Extends ReactiveCrudRepository with ReactiveMongoRepository
    - Offers more querying capabilities
  - Example – connecting and querying log results show reactor & handler threads:

```
INFO 7072 --- [localhost:27017] org.mongodb.driver.connection : Opened connection
              [connectionId{localValue:1, serverValue:29}] to localhost:27017
INFO 7072 --- [localhost:27017] org.mongodb.driver.cluster : Monitor thread successfully connected to server
              with description ServerDescription{
                   address=localhost:27017, type=STANDALONE, state=CONNECTED, ok=true,
                   version=ServerVersion{versionList=[4, 0, 1]}, minWireVersion=0, maxWireVersion=7,
                   maxDocumentSize=16777216, logicalSessionTimeoutMinutes=30, roundTripTimeNanos=2740937}
INFO 7072 --- [ntLoopGroup-2-2] org.mongodb.driver.connection
```

Reactive Repository with MongoDB

- Configuration
  - MongoDB Server
    - Standalone
      - Download from: https://www.mongodb.com/download-center#community
    - Embedded MongoDB
      - Add Maven dependencies:

```
<dependency>
    <groupId>de.flapdoodle.embed</groupId>
    <artifactId>de.flapdoodle.embed.mongo</artifactId>
    <version>1.50.5</version>
</dependency>
<dependency>
    <groupId>cz.jirutka.spring</groupId>
    <artifactId>embedmongo-spring</artifactId>
    <version>RELEASE</version>
</dependency>
```

Reactive Repository with MongoDB

- Configuration
  - Maven dependency
    - Reactive driver for MongoDB & Spring reactive repositories
    - If MongoDB is installed – this is the only dependency required

```
<dependency>
        <groupId>org.springframework.boot</groupId>
        <artifactId>spring-boot-starter-data-mongodb-reactive</artifactId>
</dependency>
```

Reactive Repository with MongoDB

- Configuration
  - Spring property `spring.data.mongodb.database` is set to ‘reactive’ by default
    - Sets/creates DB name
    - Optional, default name is ‘test’

```
spring.data.mongodb.database=reactiveDB
```

  - SpringBoot also uses ‘localhost’ and 27017 as default port

Reactive Repository with MongoDB

- Creating repository

```
public interface ReactivePersonRepository extends ReactiveCrudRepository<Person, String>{
        Flux<Person> findAllByAge(int age);
}
```

```
@Document
public class Person {

        @Id
        private String id;
        private String name;
        private int age;

        //getters & setters
        ...
}
```

Reactive Repository with MongoDB

- Using reactive repository with REST

```
@RestController
@RequestMapping(“person")
public class ReactiveTodoController {

        @Autowired
        private ReactiveTodoRepository repo;

        @GetMapping(value="add/{id}/{name}/{age}", produces=MediaType.TEXT_EVENT_STREAM_VALUE)
        public Mono<Person> add( @PathVariable("id") String id,
                                 @PathVariable(“name") String name,
                                 @PathVariable(“age") int age) {
                Person p=new Person();
                p.setId(id);
                p.setName(name);
                p.setAge(age);
                return repo.save(p);
        }

        ...
```

Reactive Repository with MongoDB

- Using reactive repository with REST – cont.

```
        ...

        @GetMapping(value="all", produces=MediaType.TEXT_EVENT_STREAM_VALUE)
        public Flux<Person> getAll() {
                return repo.findAll();
        }

        @GetMapping(value="all/age/{age}", produces=MediaType.TEXT_EVENT_STREAM_VALUE)
        public Flux<Person> getAll(@PathVariable("age") int age) {
                return repo.findAllByAge(age);
        }

}
```

Reactive Repository with MongoDB

- Testing:
  - /person/add/a/David/20

```
data:{"id":"a", "name":"David", "age":20}
```

  - /person/all

```
data:{"id":“b", "name":“Bob", "age":35}

data:{"id":“y", "name":“Eve", "age":20}

data:{"id":“w", "name":“Dan", "age":45}

data:{"id":"a", "name":"David", "age":20}
```

  - /person/all/age/20

```
data:{"id":“y", "name":“Eve", "age":20}

data:{"id":"a", "name":"David", "age":20}
```