Near Real-Time Stream Analysis

Design and Implementation of a High-Performance Stream-Oriented Processing System

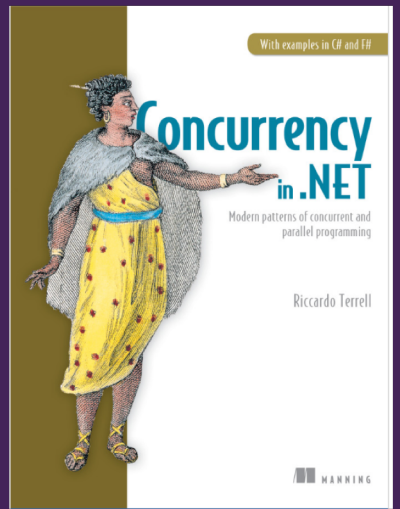
BY RICCARDO TERRELL - @RIKACE

Agenda

- What & Why Reactive Streams
- Concepts and goals of Reactive Stream
- Back pressure and how the Actor programming model fit
- How to design high-performant Stream-Processing
- Stream-Processing in action with Akka.Streams and F#

Introduction - Riccardo Terrell

- Originally from Italy, currently - Living/working in Charlotte, NC
- +/- 20 years in professional programming
  - C++/VB → Java → .Net C# → Scala → Haskell → C# & F# → ??
- Author of the book “Functional Concurrency in .NET” – Manning Pub.
- *Polyglot programmer - believes in the art of finding the right tool for the job*
- *Organizer of DC F# User Group and Pure Functional DC*



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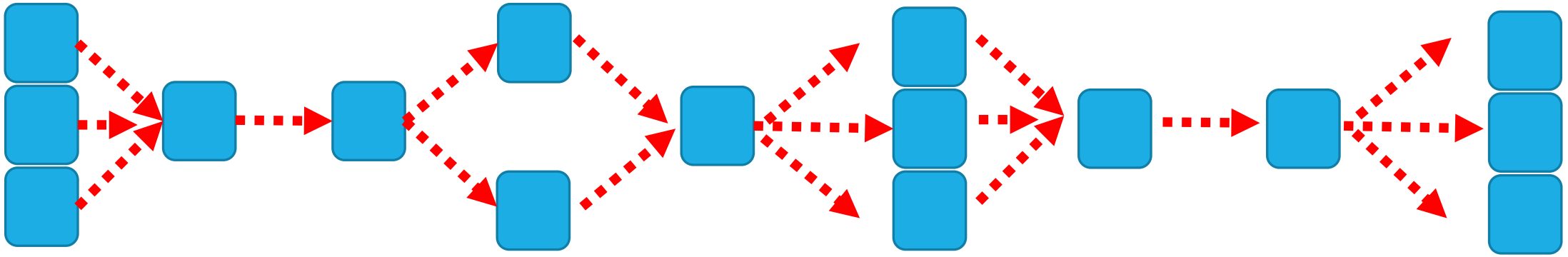
What is a Stream?

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

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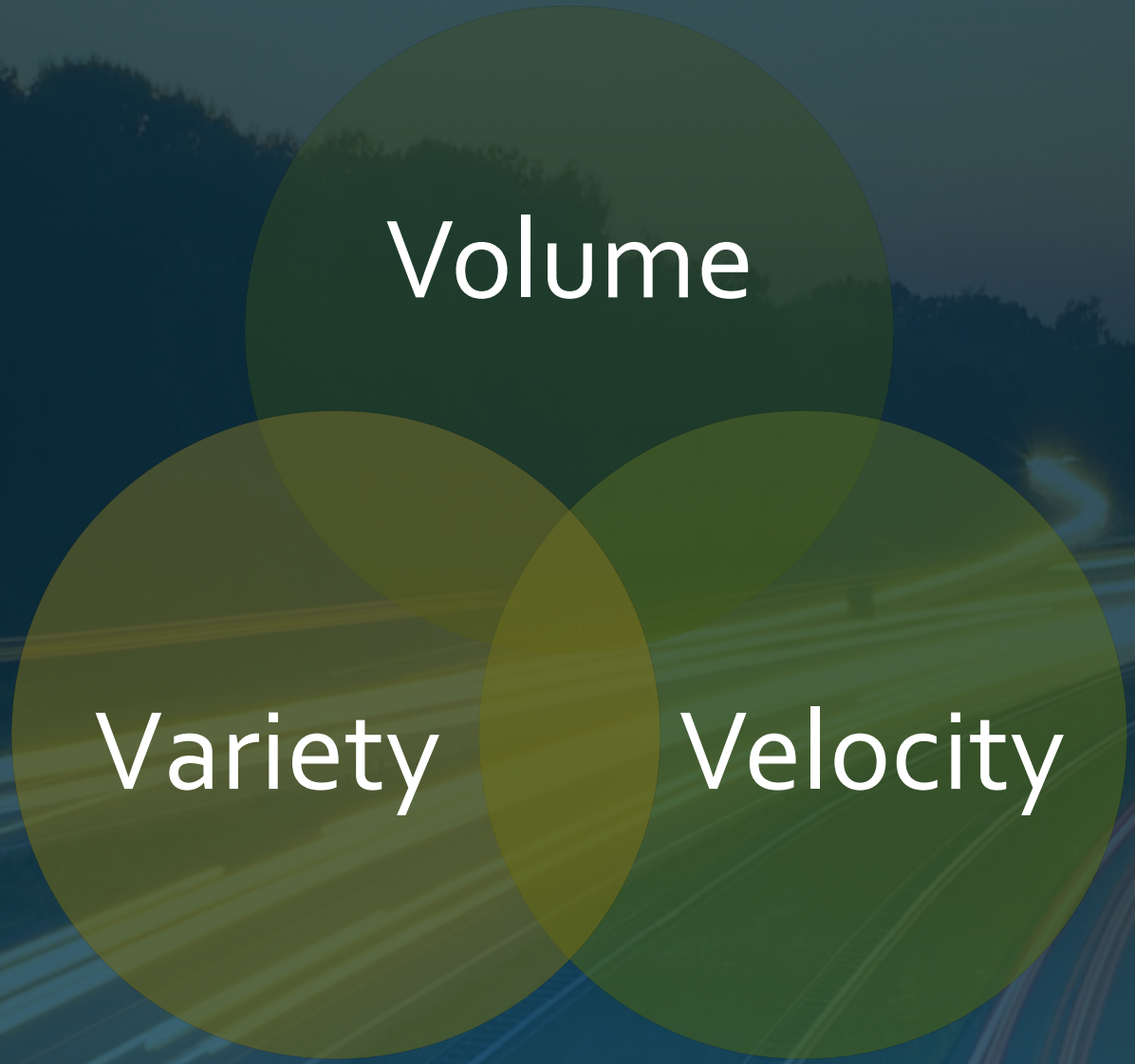
Data in motion

The 3 V's of data in motion



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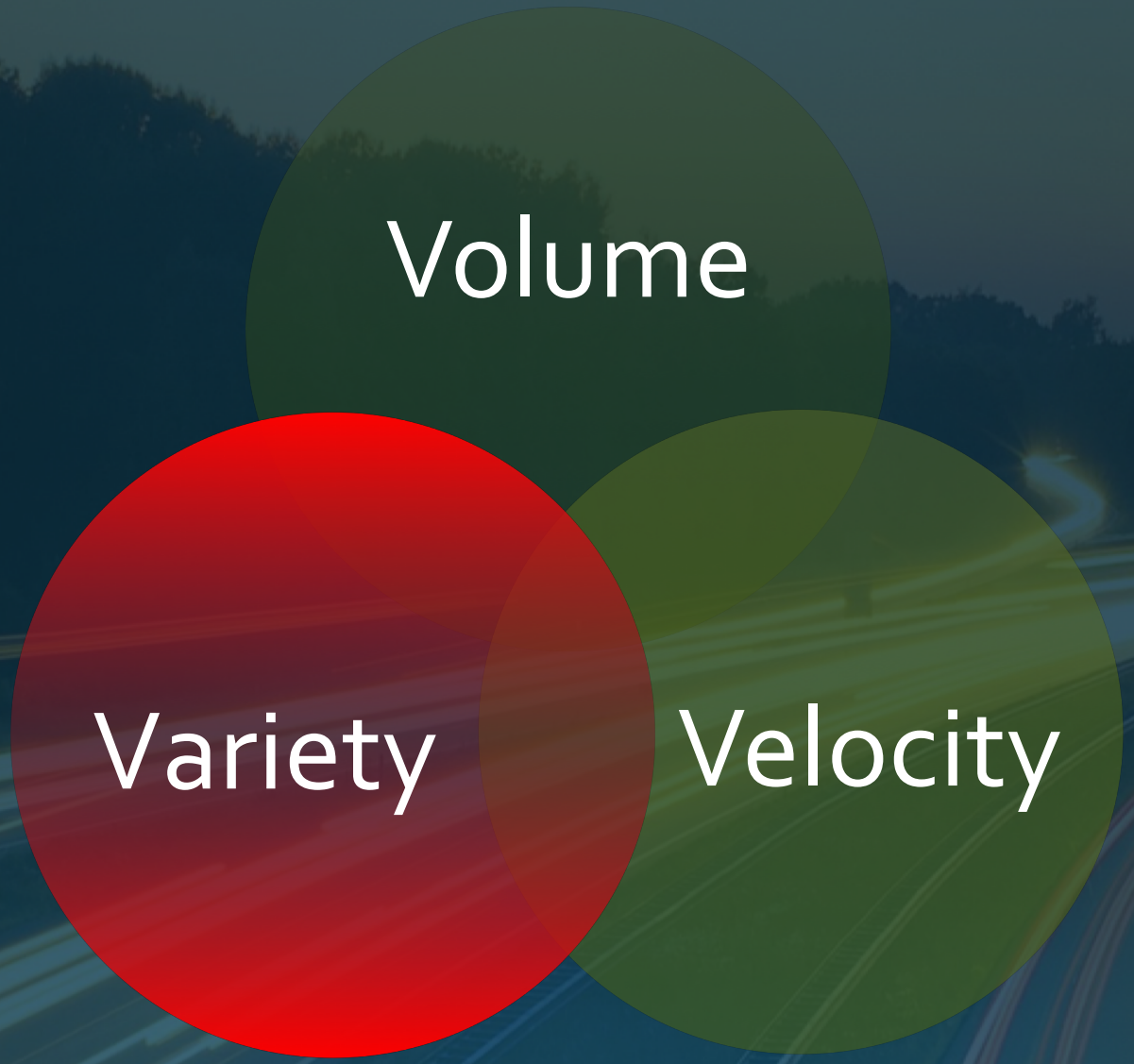

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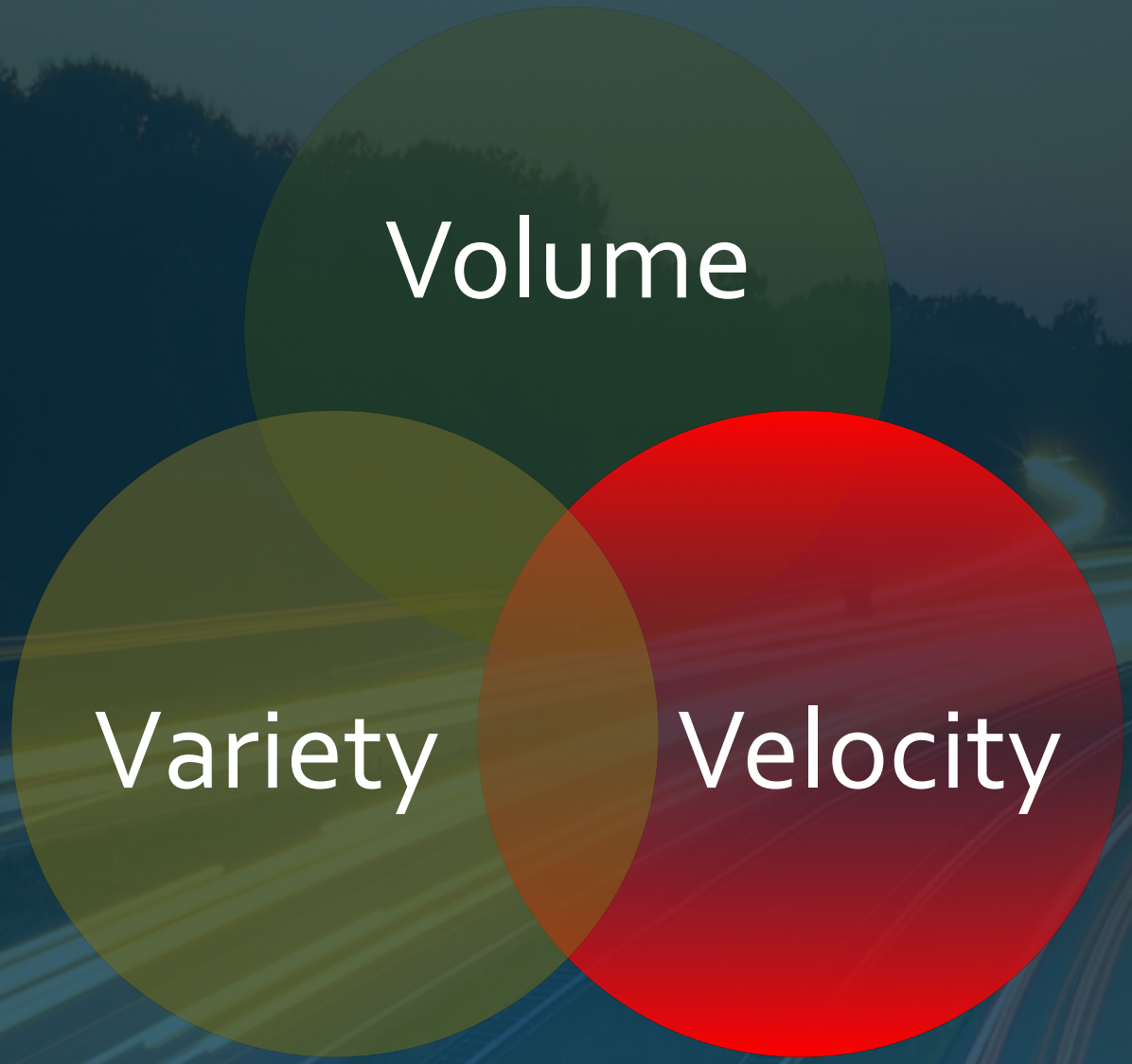
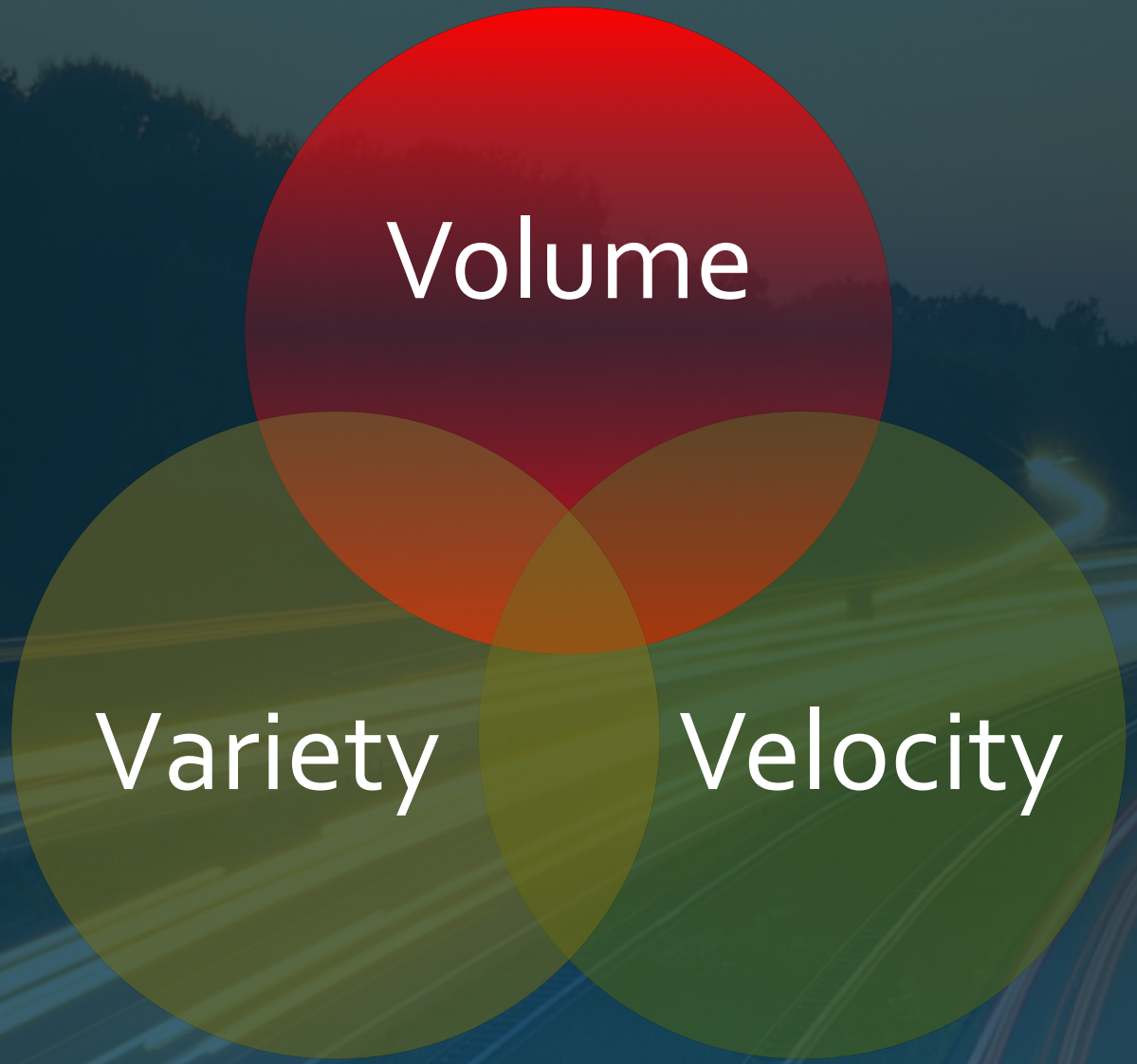


The 3 V's of data in motion



The 5 V's of data in motion

Volume

Variety

Velocity

Value

Veracity

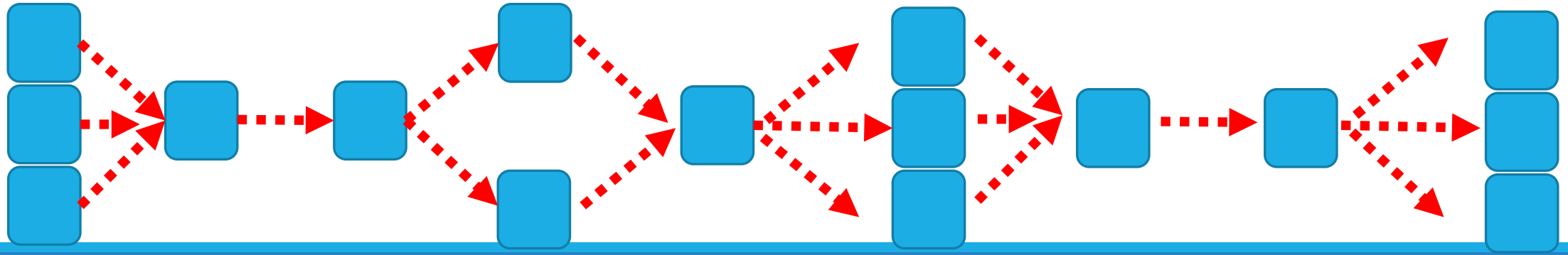
Attributes for a scalable Stream-Processing system

Asynchronous : The process has to be asynchronous in order to ensure optimal utilization of computing resources

Nonblocking : This is required to ensure bounded latency

Elastic for handling back pressure : This is needed when producers push data toward consumers and the consumer may be processing at a slower rate than what the producer is generating.

Compositional : This is a quality that we demand all APIs should have. This will lead to a better programming model.



Reactive Programming

(and Stream Processing)

reactive programming is a programming paradigm that maintains a continuous interaction with their environment, but at a speed which is determined by the environment, not the program itself

Gèrard Berry

Reactive Streams – Properties and Design

“Reactive Streams is an initiative to provide a standard for asynchronous stream processing with non-blocking back pressure. This encompasses efforts aimed at runtime environments (JVM and JavaScript) as well as network protocols

http://www.reactive-streams.org

- asynchronous
- stream processing
- non-blocking back pressure

Reactive Systems – Properties and Design

Event Driven : react to events (events are data), events can be handled asynchronously

Scalable : react to load serving numerous clients simultaneously with bounded resources

Responsive : react to load responding in a timely manner if at all possible.

Resilient : react to failures The system stays responsive in the face of failure.

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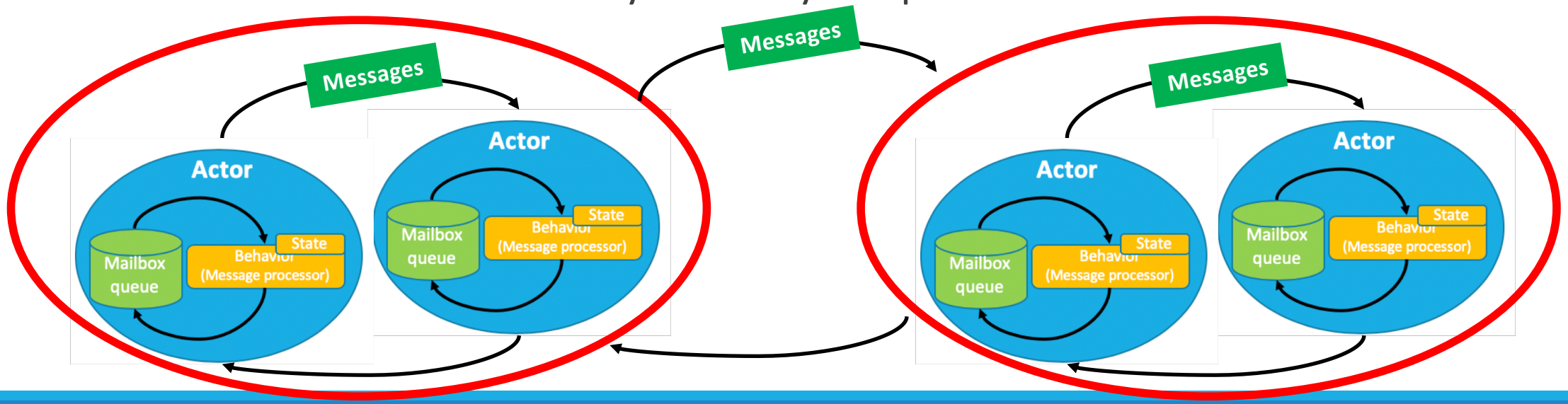
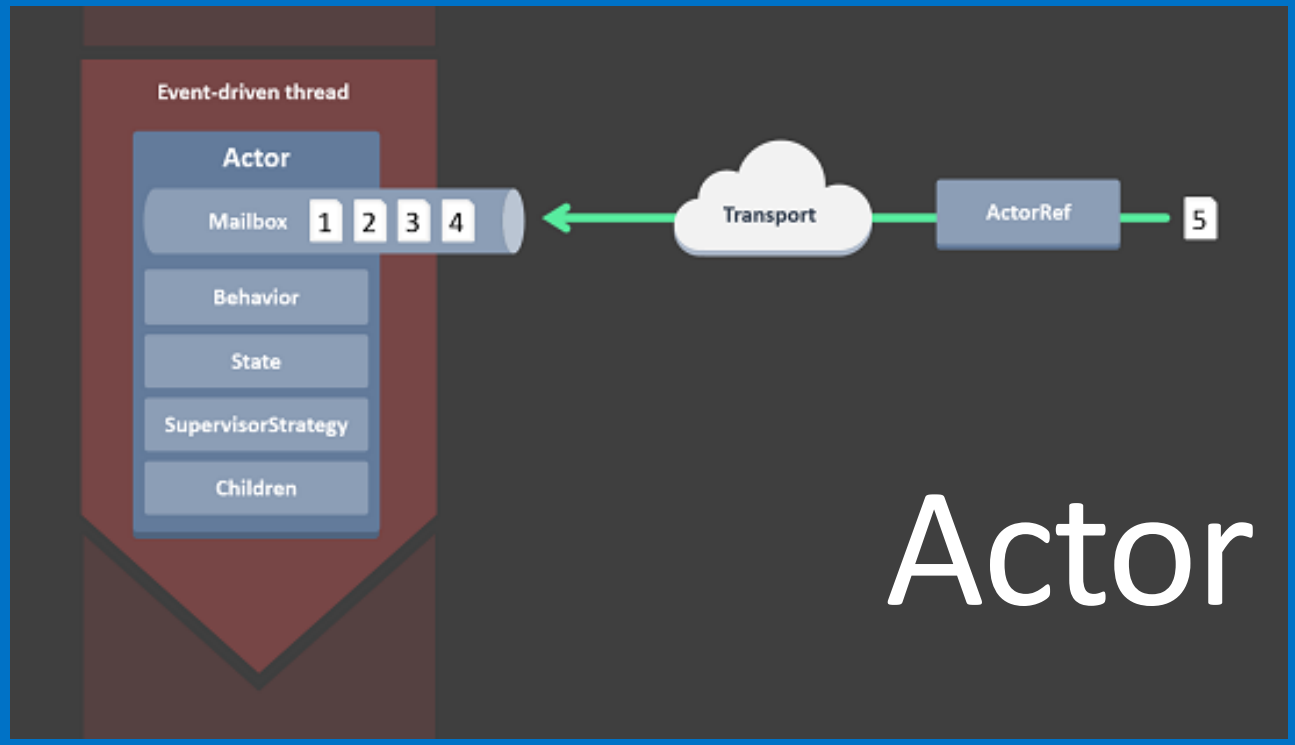


From



Actor Model

to Reactive Streams

What an Actor Offers

High Throughput

Fault tolerance

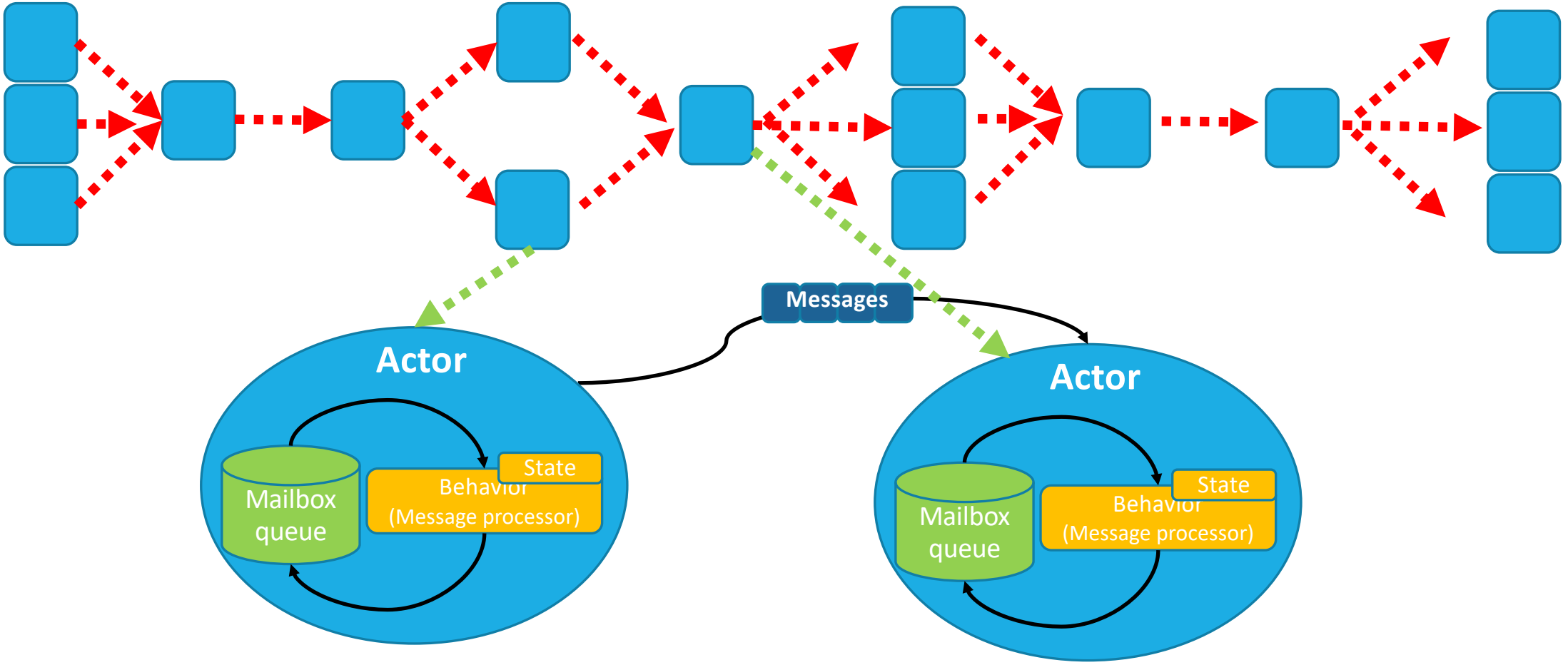
No manual thread management

Scale Out & Up

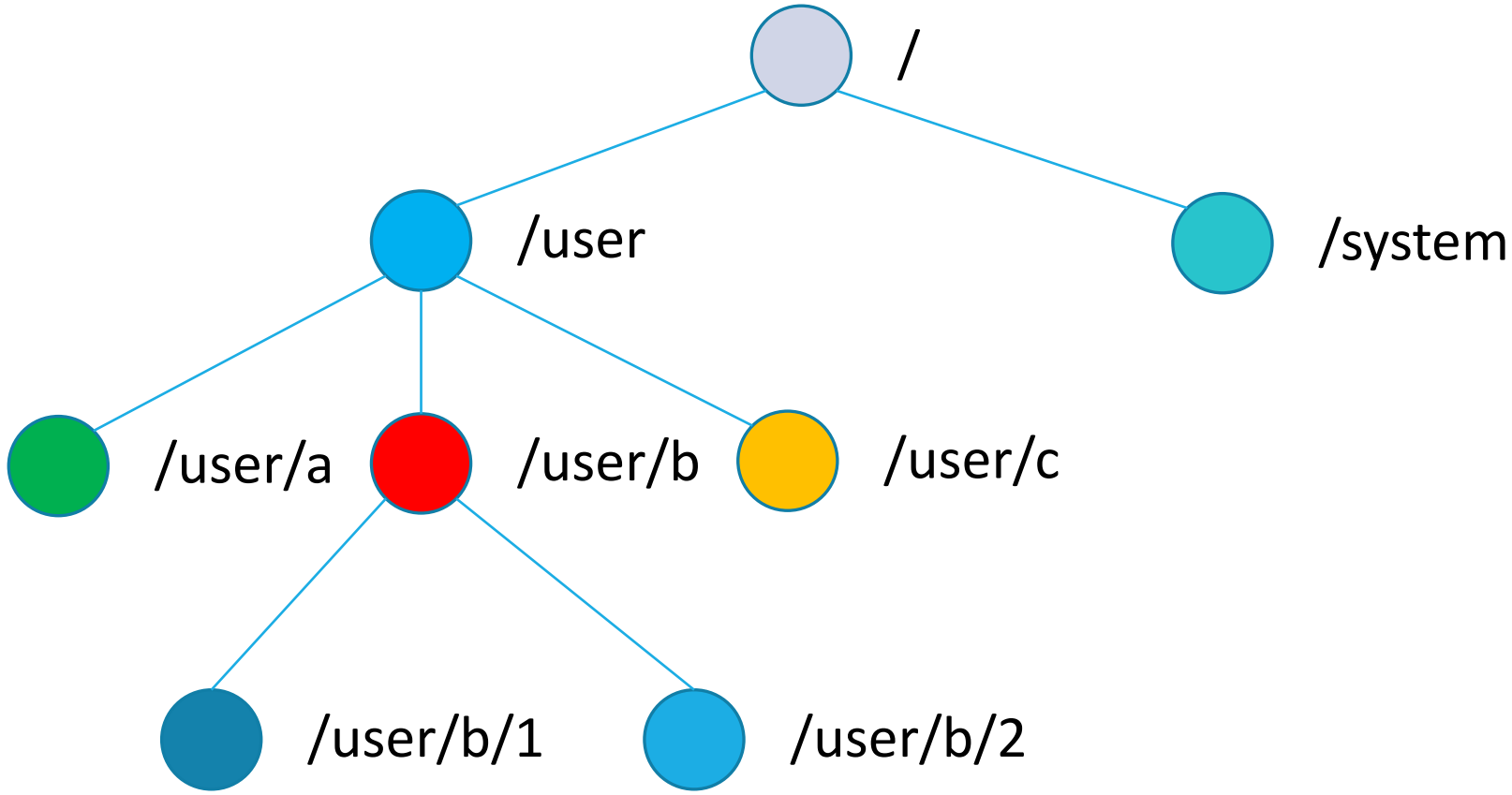
High Availability

Asynchronous

Message Passing & Stream Modeling



From Actors to Streams
actors are hard to compose



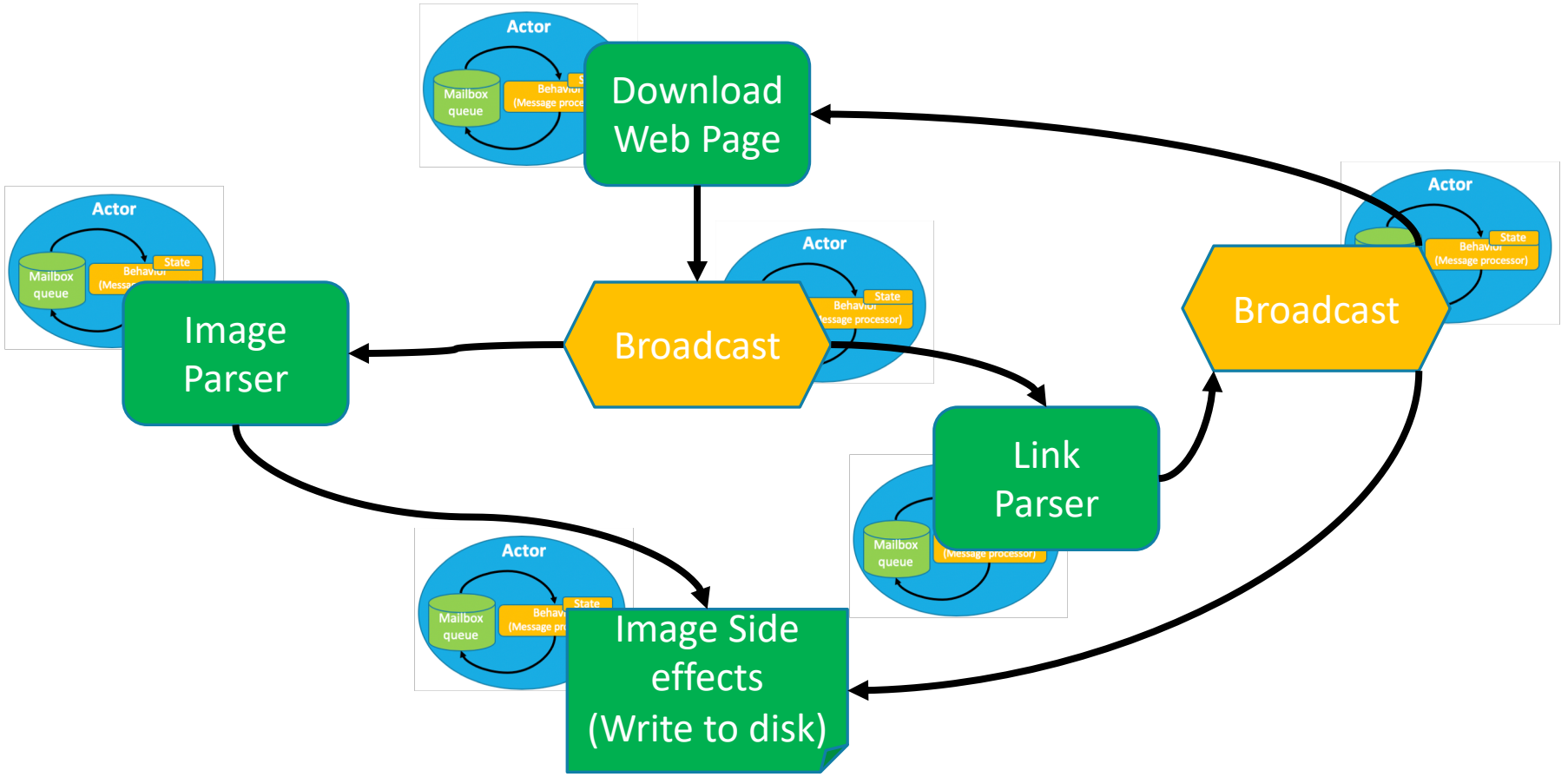
Actor implementation class in F#

```
let behavior (f:'a -> Async<'b>) (m:Actor<'a>) =
    let rec loop () = actor {
        let! msg = m.Receive ()
        printfn "Actor received : %O" msg
        let! res = f msg
        m.Context.Sender() <! res
        return! loop ()
    }
    loop ()
```

Actor implementation class in F#

```
let behavior (f:'a -> Async<'b>) (targetRef:ICanTell<'b>) (m:Actor<'a>) =
    let rec loop () = actor {
        let! msg = m.Receive ()
        printfn "Actor received : %O" msg
        let! res = f msg
        targetRef <! res
        return! loop ()
    }
    loop ()
```

Actors are hard to compose
An Actor-based WebCrawler



What if we could describe the data flow process on a higher level?

Like a in LINQ

```
var results = ctx.Employee
                 .Join(ctx.Manager,
                     c => c.EmployeeID,
                     p => p.ManagerID,
                     (c, p) => new { c, p })
                 .Where(z => z.c.Hired >= fromDate)
                 .OrderByDescending(z => z.c.Salary)
                 .Select(z => z.Fullname)
                 .ToList();
```

Akka Streams

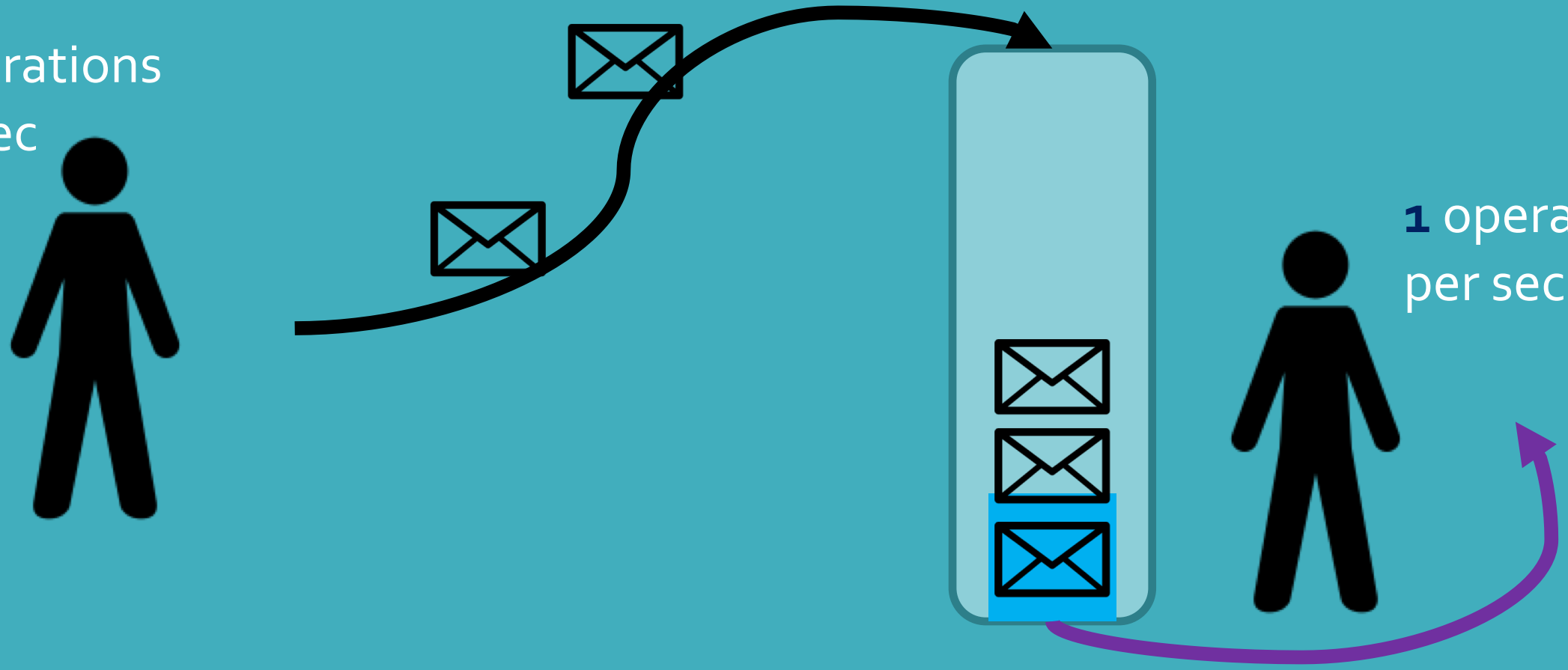
```
let merge = b.Add(new MergePreferred<Uri>(1))
let bcast = b.Add(new Broadcast<Uri>(2))

let flow =
    Flow.empty<Uri, _>
    |> Flow.asyncMapUnordered 4 downloadPageAsync
    |> Flow.collect resolveLinks

let flowBack =
    Flow.empty<Uri, _>
    |> Flow.conflateSeeded (fun (uris : ImmutableList<Uri>) uri -> uris.Add uri)
    |> Flow.collect id

b.From(bcast).Via(flowBack).To(merge) |> ignore

b.From(merge).Via(flow).To(bcast)
```

Push only model & Back-Pressure

Push Model

Subscriber usually has some kind of buffer.

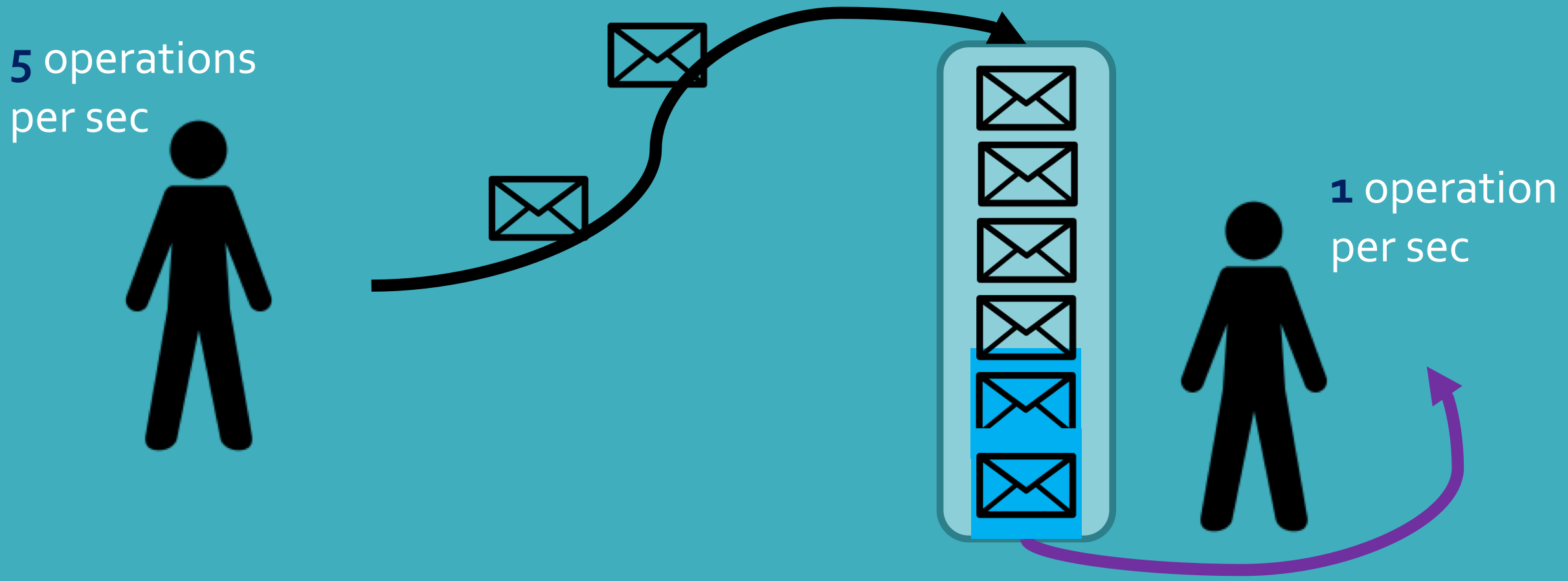
5 operations per sec



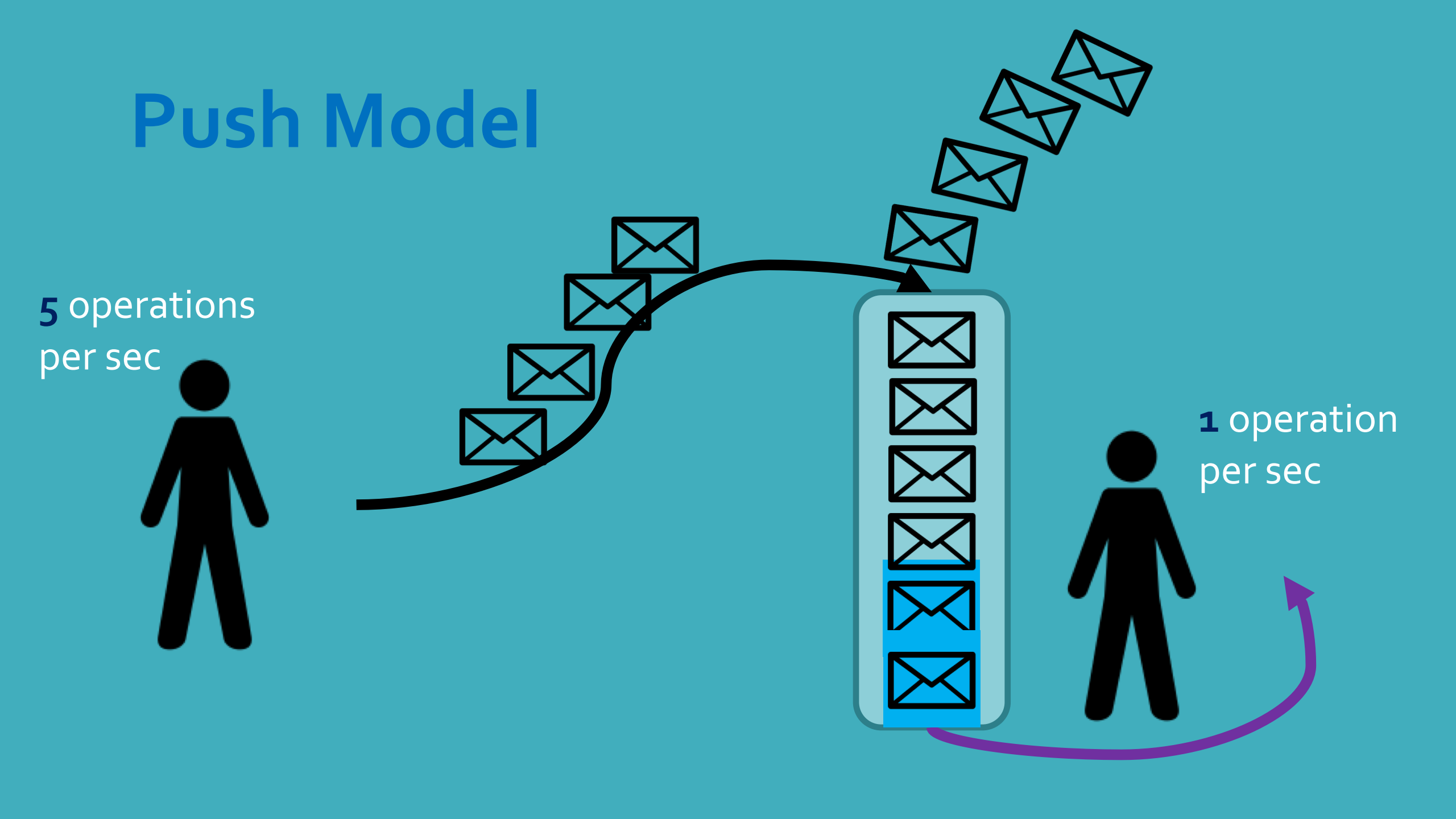
1 operation per sec

Push Model

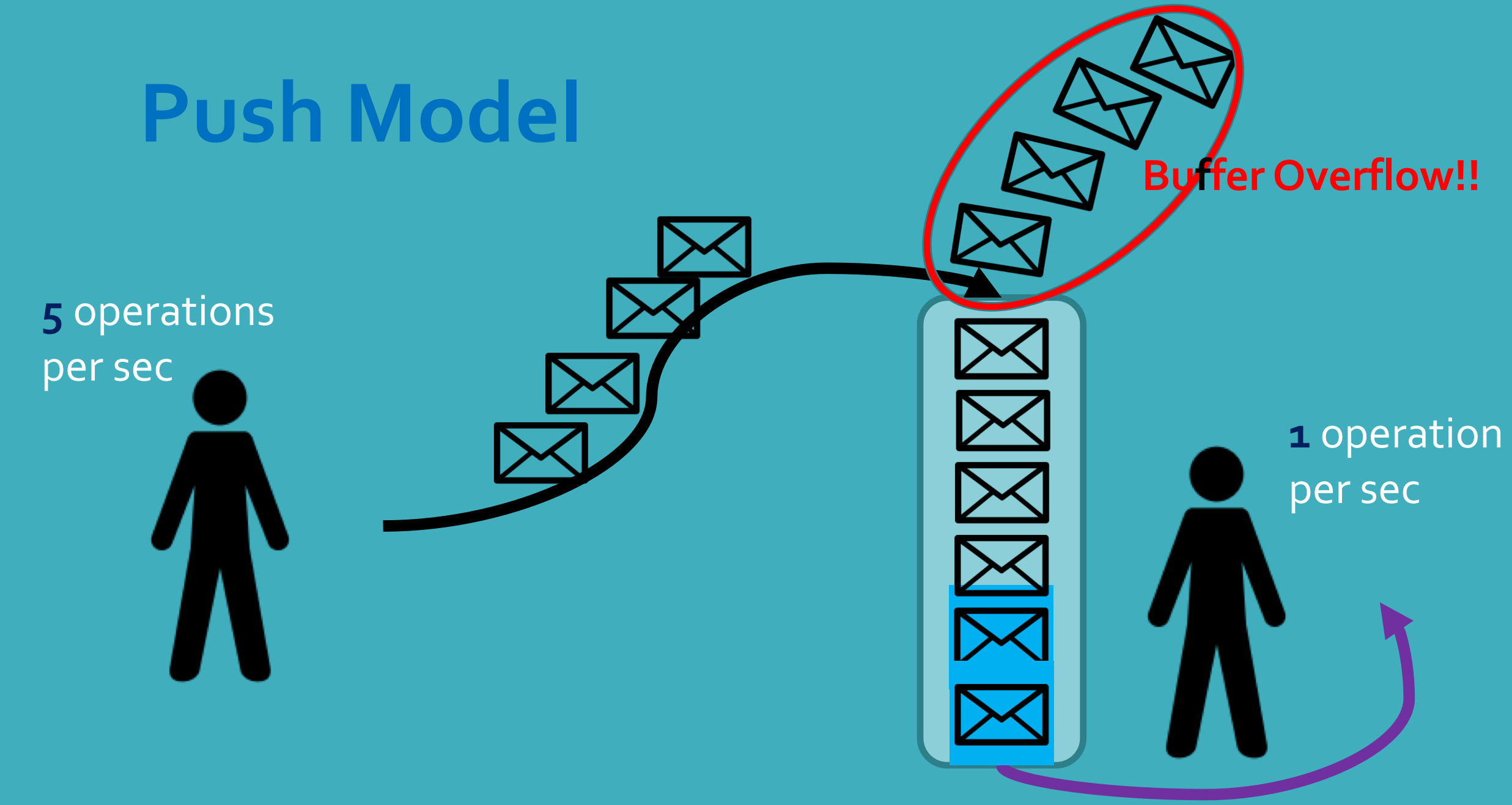
Subscriber usually has some kind of buffer.



Push Model

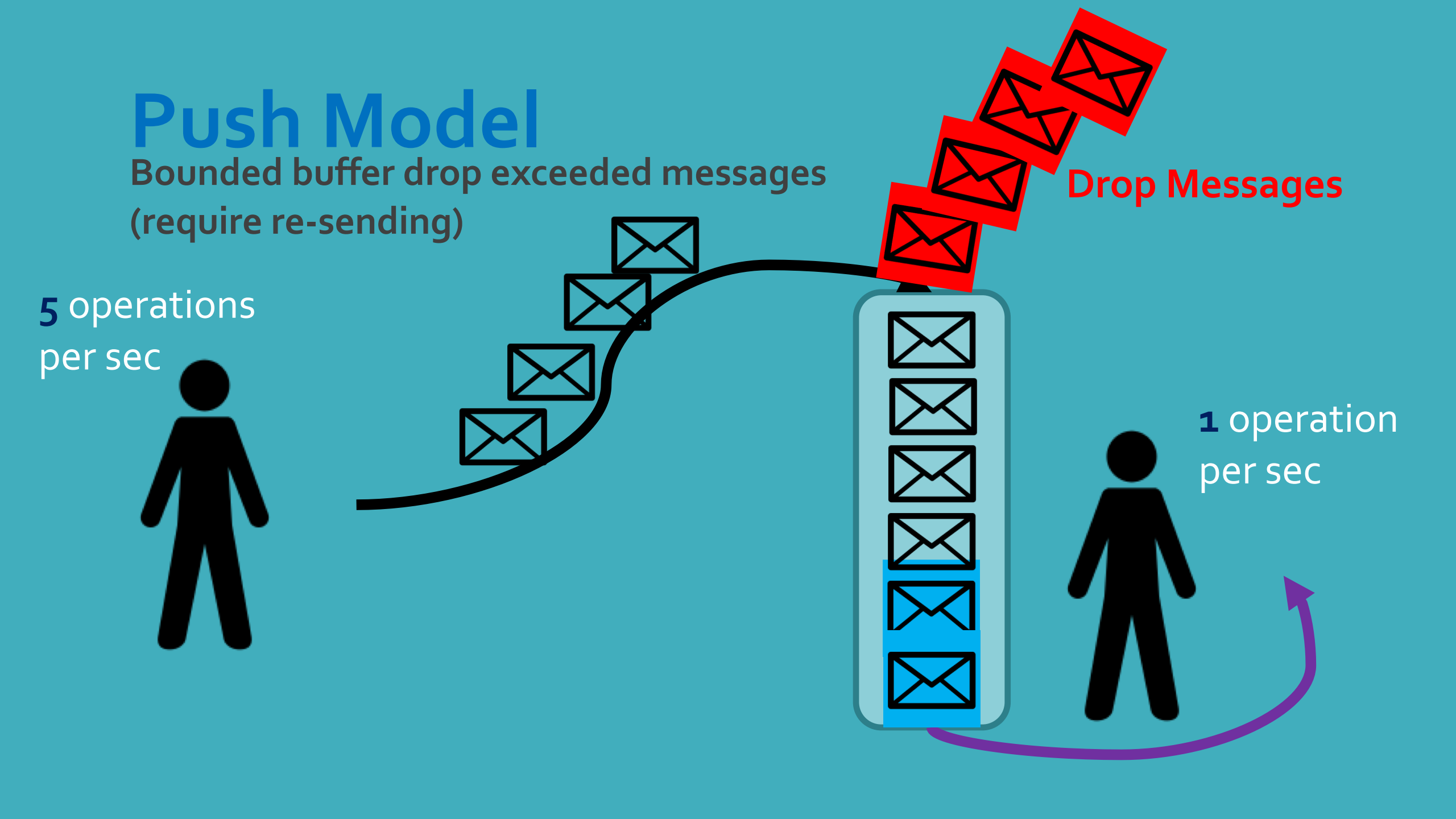


Push Model



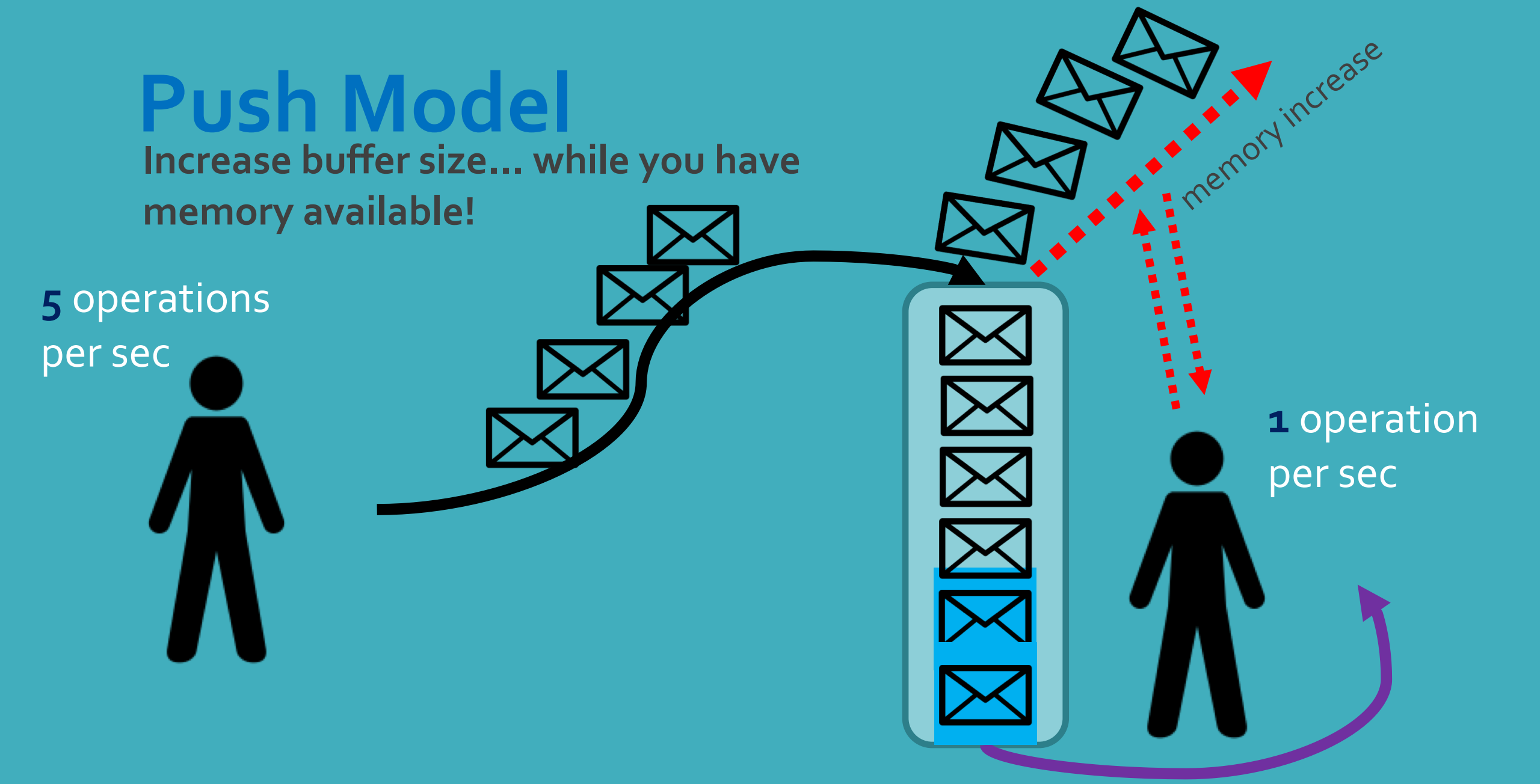
Push Model

Bounded buffer drop exceeded messages (require re-sending)

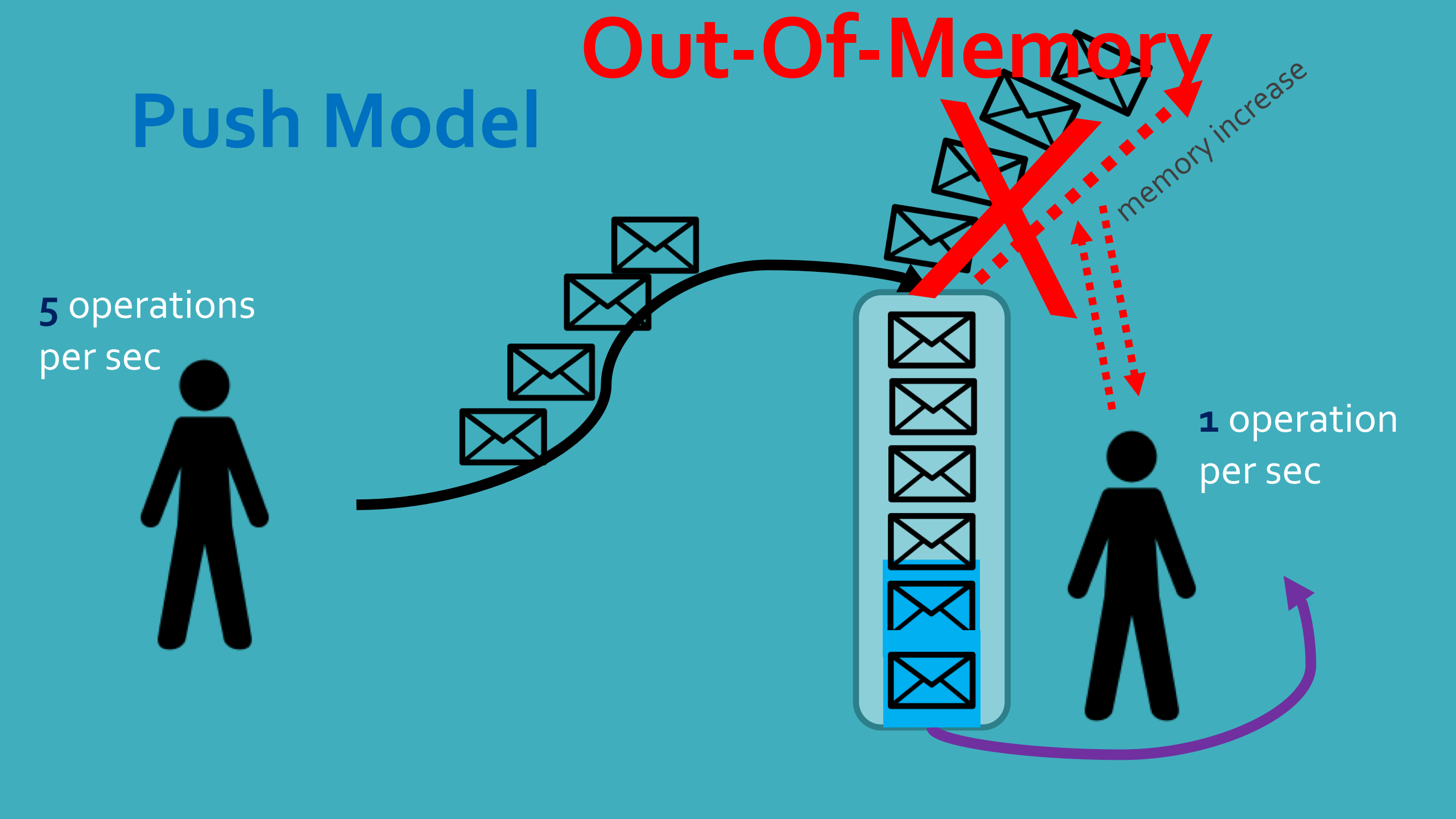


Push Model

Increase buffer size… while you have memory available!

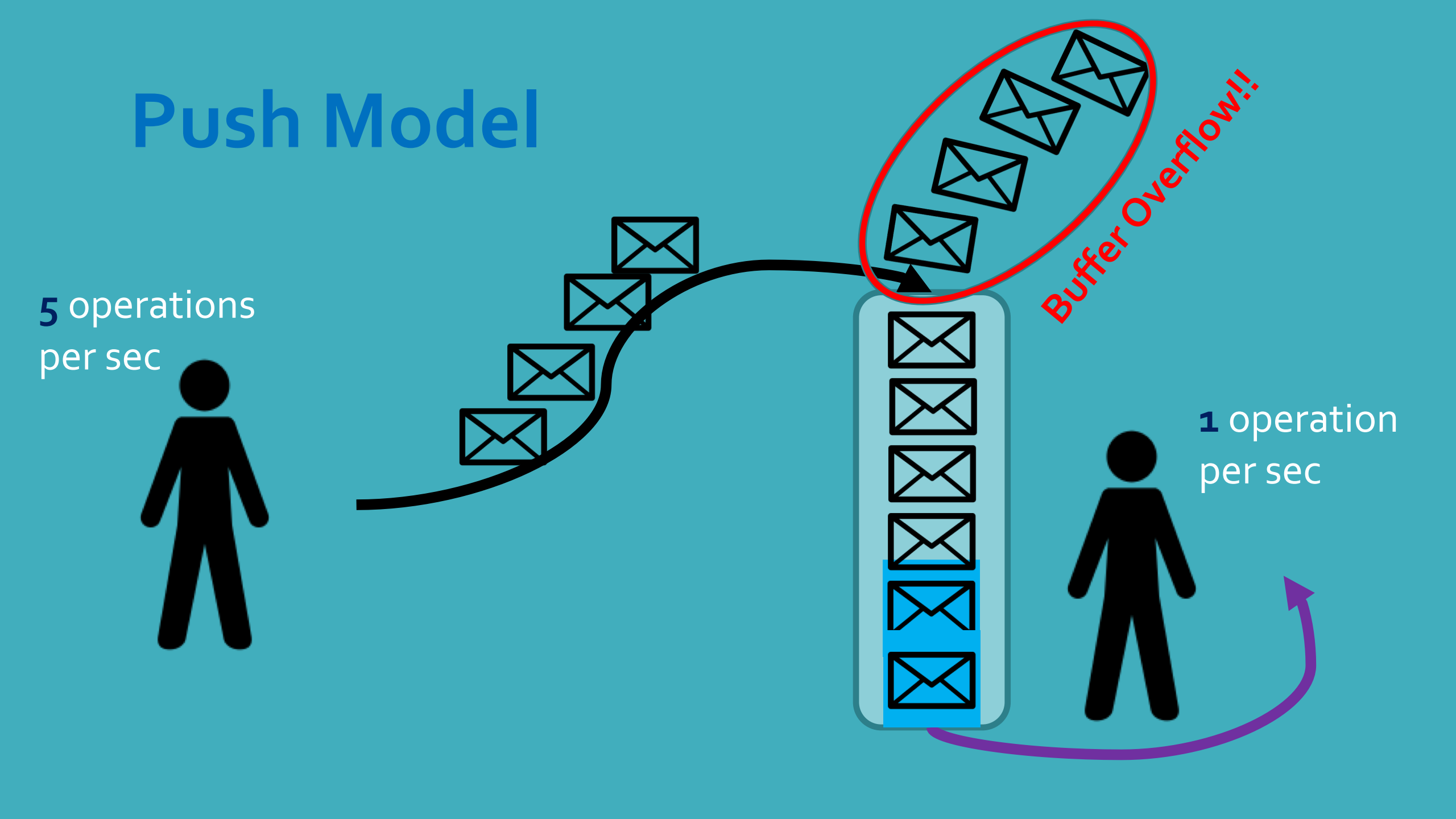


Push Model


Out-Of-Memory
memory increase
5 operations per sec
1 operation per sec

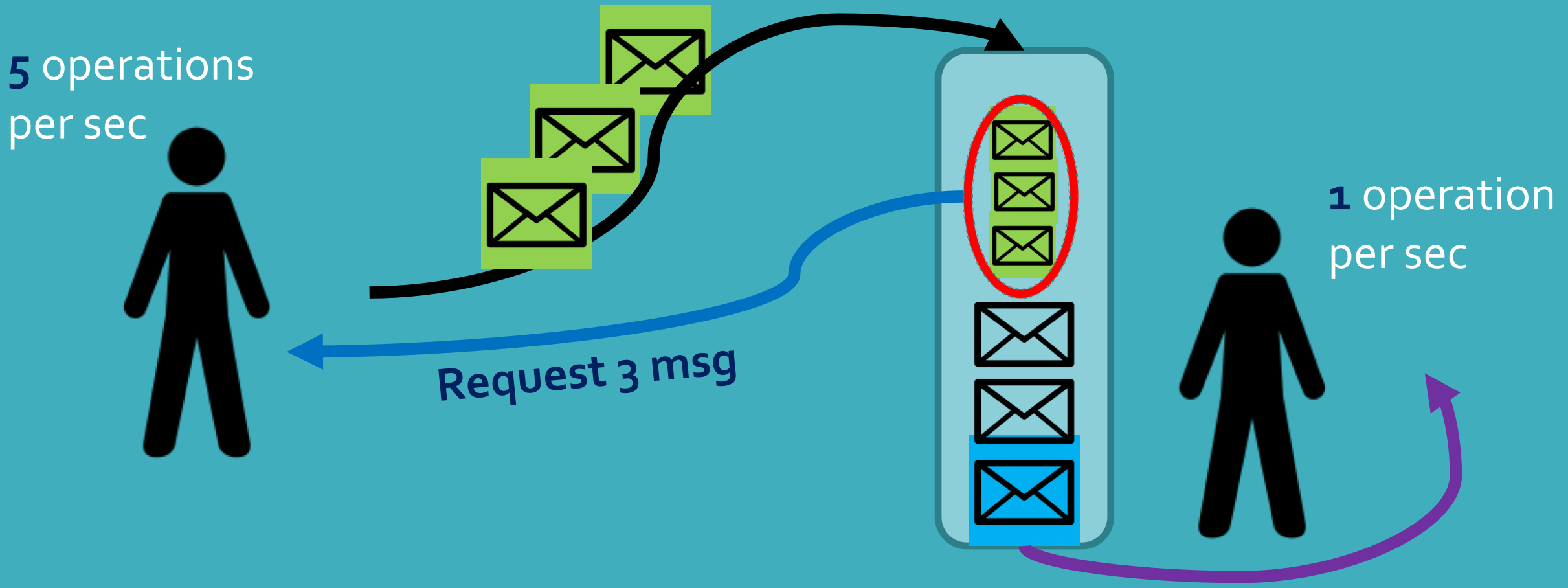
How to buffer the data without running out of memory?

Push Model

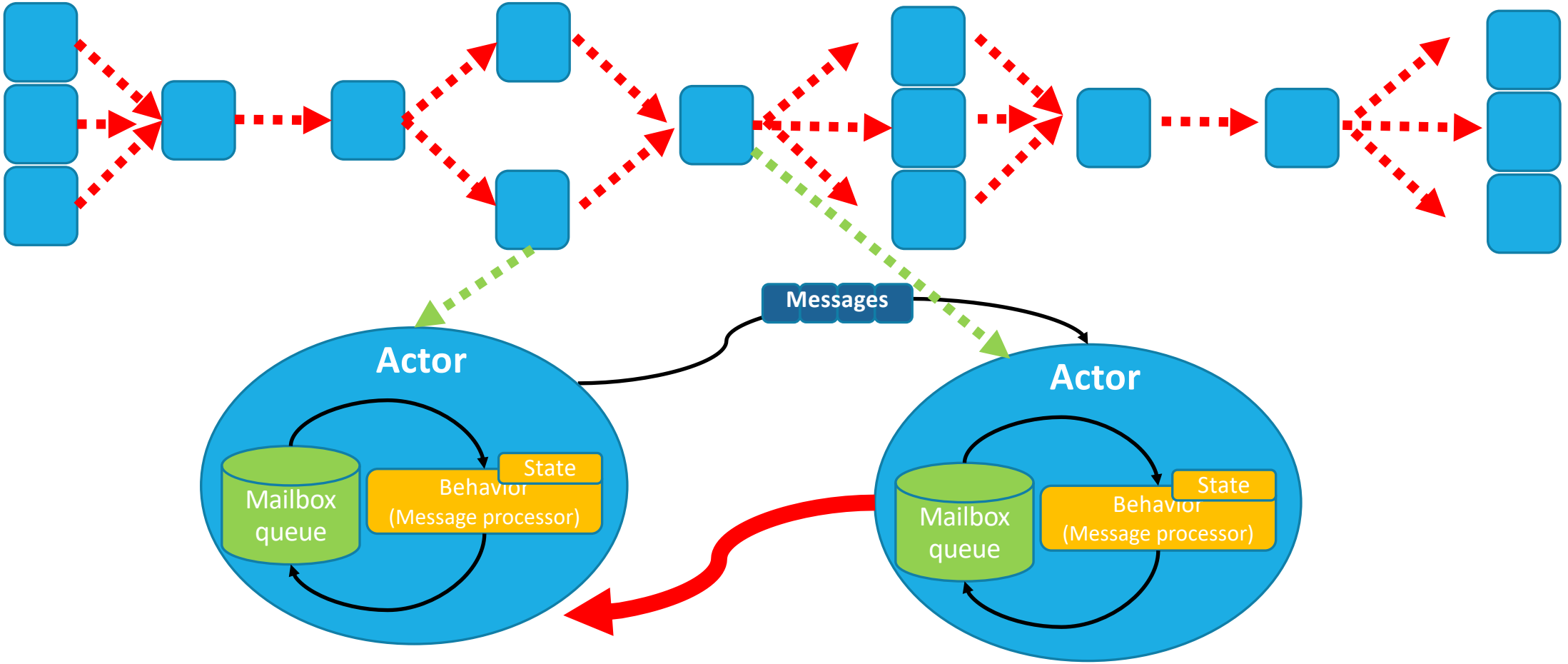


Dynamic Push-Pull

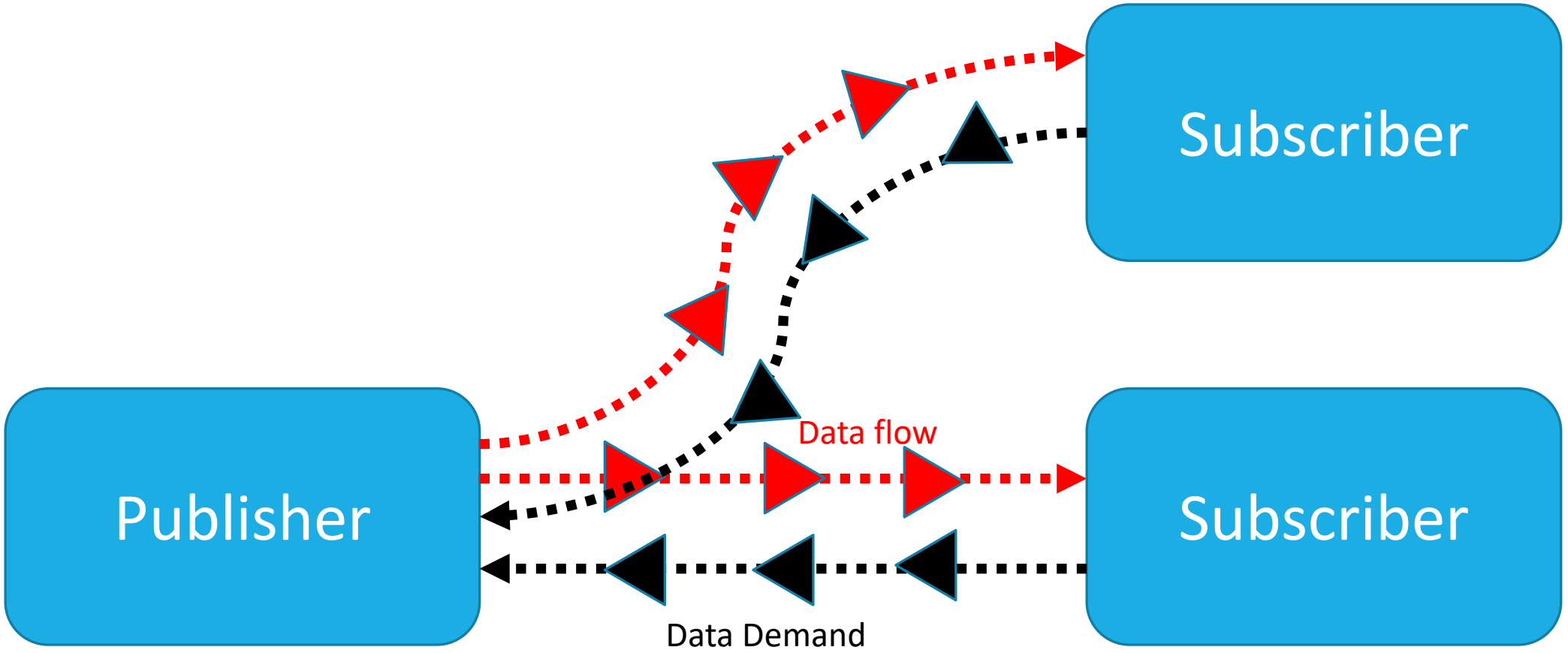
Pull based backpressure



Message Passing & Stream Modeling



Splitting and merging the data flow



Reactive Stream interfaces

```
[<Interface>]
type ISubscription =
    abstract Request : int64 -> unit
    abstract Cancel : unit -> unit

[<Interface>]
type ISubscriber<'a> =
    abstract OnSubscribe : ISubscription -> unit
    abstract OnNext : 'a -> unit
    abstract OnError : Exception -> unit
    abstract OnComplete : unit -> unit

[<Interface>]
type IPublisher<'a> =
    abstract Subscribe : ISubscriber<'a> -> unit
```

Akka Streams

- Streams complement Actors, they do not replace them
- Modular and composable
- Leveraging Actors distribution and supervision
- Easily concurrent and parallel
- Back pressure handling

Materializing a stream

```
var runnable =
    Source
        .From(Enumerable.Range(1, 1000))
        .Via(Flow.Create<int>().Select(x => x * 2)
        .To(Sink.ForEach<int>(x => Console.Write(x.ToString));
```

Materializing a stream

```
var runnable =
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        .From(Enumerable.Range(1, 1000))
        .Via(Flow.Create<int>().Select(x => x * 2)
        .To(Sink.ForEach<int>(x => Console.Write(x.ToString));

var system = ActorSystem.Create("MyActorSystem");
using (var materializer = ActorMaterializer.Create(system))
{
    await runnable.Run(materializer);
}
```
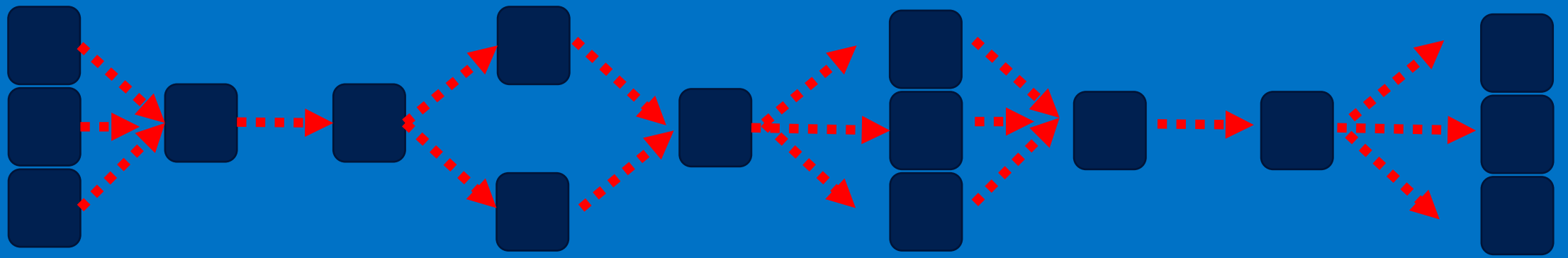
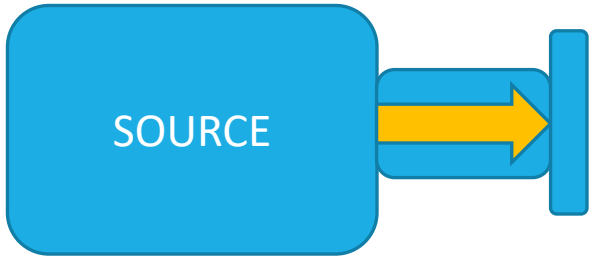

Reactive Stream compose



Elements of a Stream

Source : This is where the pipeline starts. A Source takes data from input and has a single output to be written into.



Elements of a Stream

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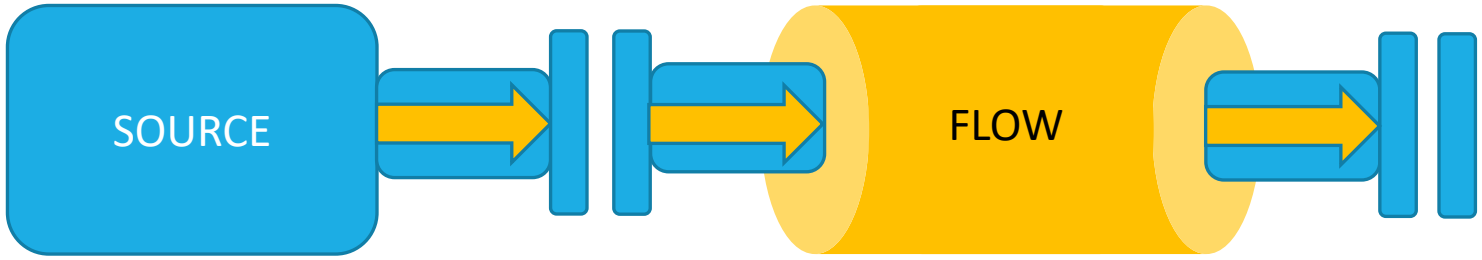
Flow : This is the basic abstraction where transformation of data takes place. A Flow has one input and one output.

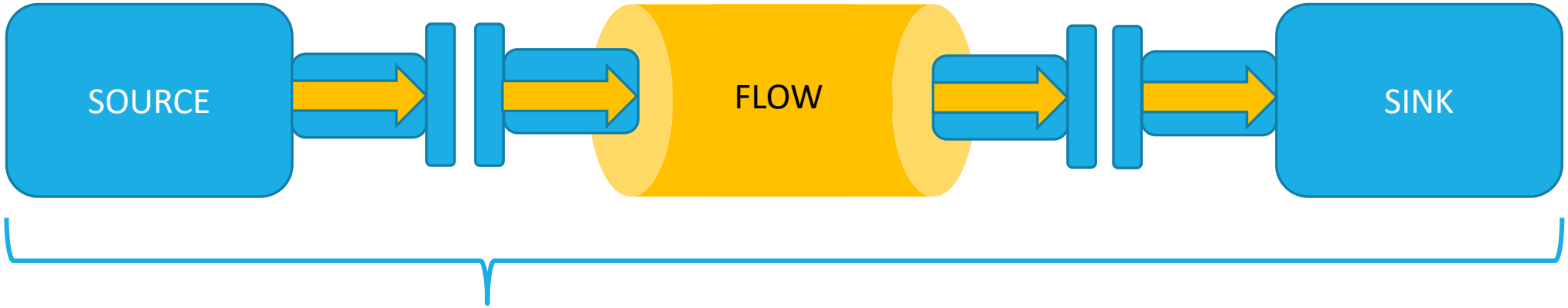


Elements of a Stream

Source : This is where the pipeline starts. A Source takes data from input and has a single output to be written into.

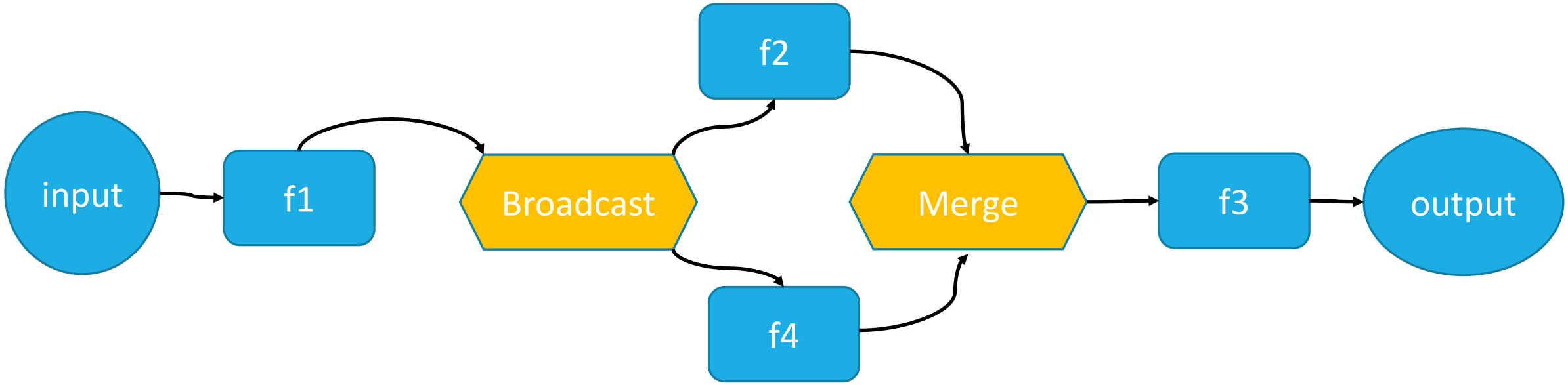
Flow : This is the basic abstraction where transformation of data takes place. A Flow has one input and one output.

Sink : The pipeline ends here. A Sink has a single input to be written into.

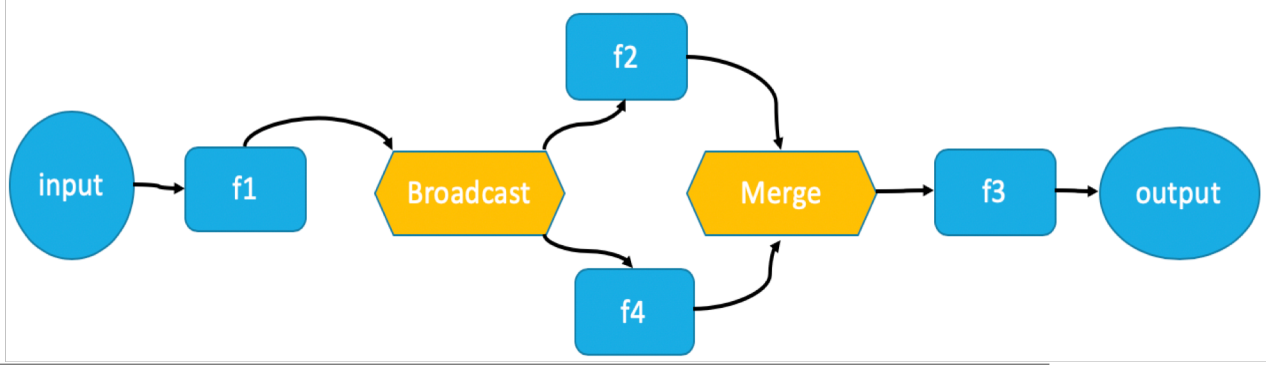


RunnableGraph represents the entire topology (Source -> Flow* -> Sink)

GraphDSL



Graph DSL in F#

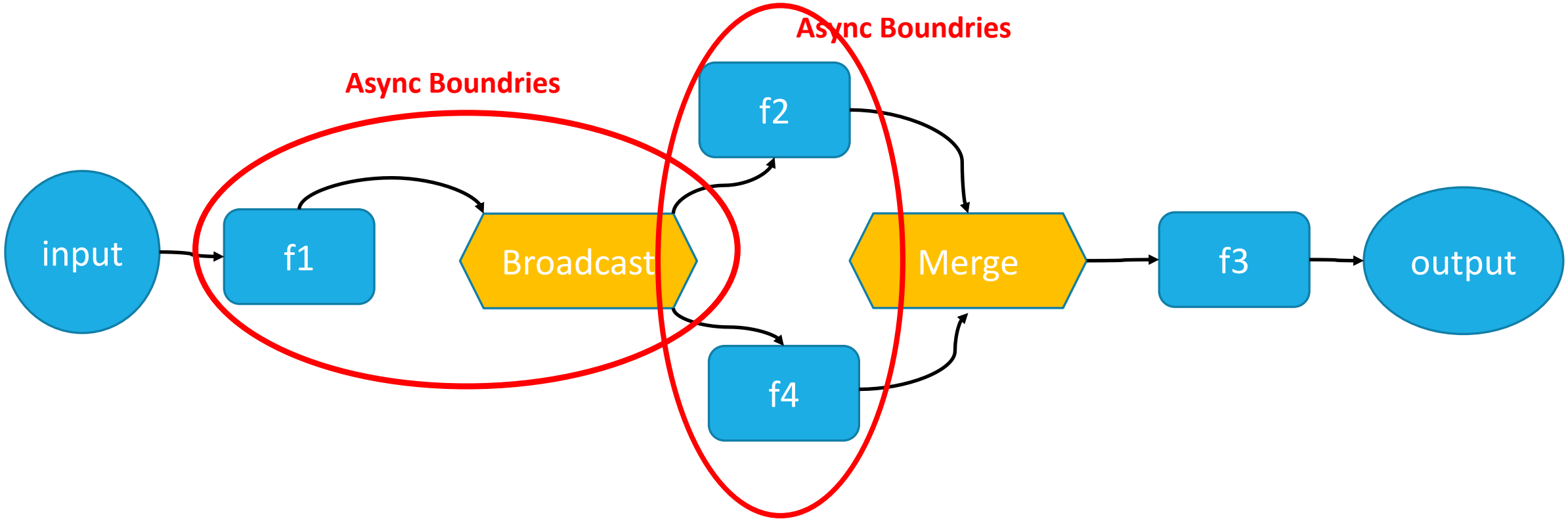



```
let graph = Graph.create(fun builder ->
    let source = Source.from(Enumerable.Range(1, 10))
    let sink = Sink.Ignore<int>().MapMaterializedValue(fun _ -> NotUsed.Instance)

let broadcast = builder.Add(new Broadcast<int>(2))
    let merge = builder.Add(new Merge<int>(2))

    let f1 = Flow.Create<int>().Select(fun x -> x + 10)
    let f2 = Flow.Create<int>().Select(fun x -> x + 10)
    let f3 = Flow.Create<int>().Select(fun x -> x + 10)
    let f4 = Flow.Create<int>().Select(fun x -> x + 10)

    builder.From(source).Via(f1).Via(broadcast).Via(f2).Via(merge).Via(f3).To(sink)
    builder.From(broadcast).Via(f4).To(merge)
    ClosedShape.Instance )
```

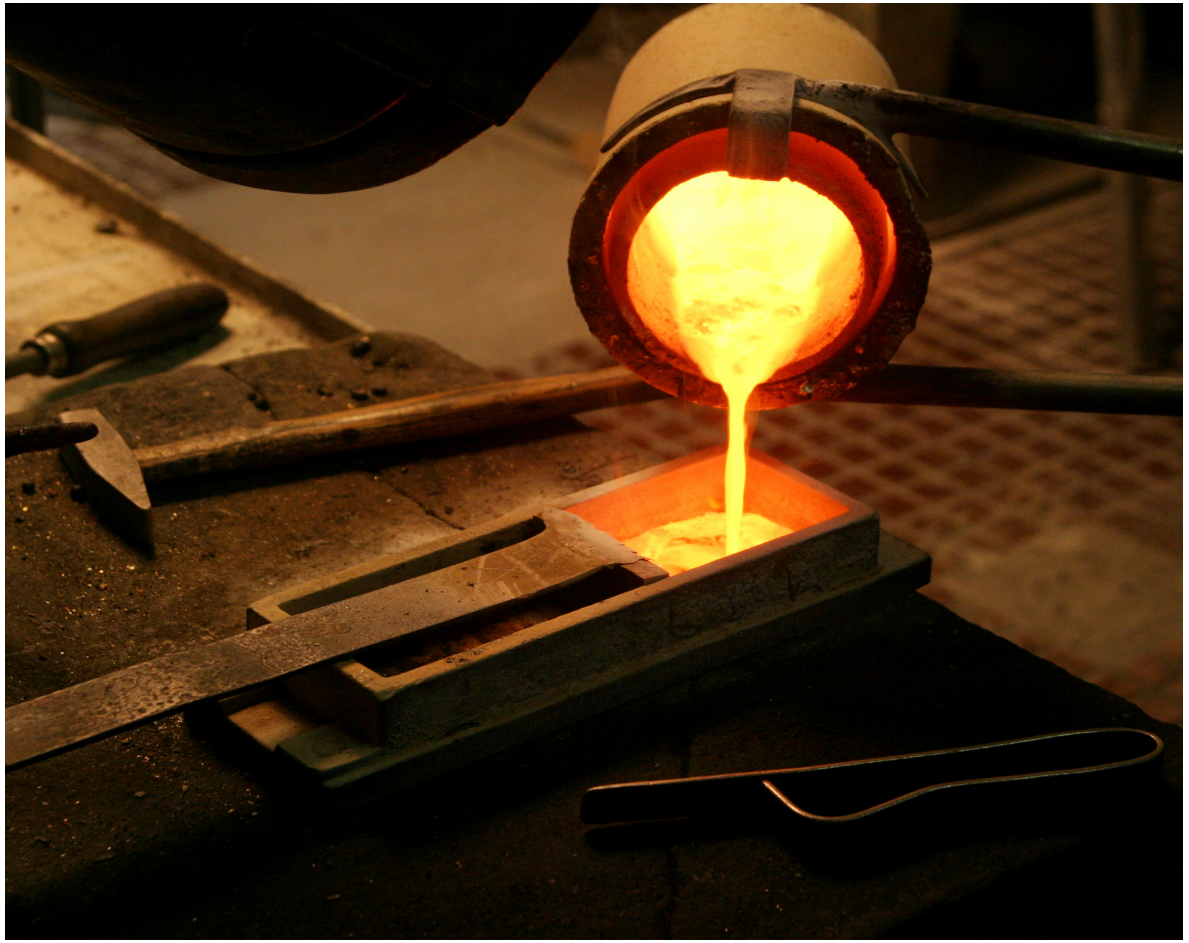
Implementing High performant Stream-Processing with Reactive Stream

Throughput Throughput Throughput

Async Boundaries



Stream – Operator fusion



- Fast elements passing elements processing stage to the next
- Avoid asynchronous messaging overhead
- Explicit parallel processing across boundaries

Async Boundaries

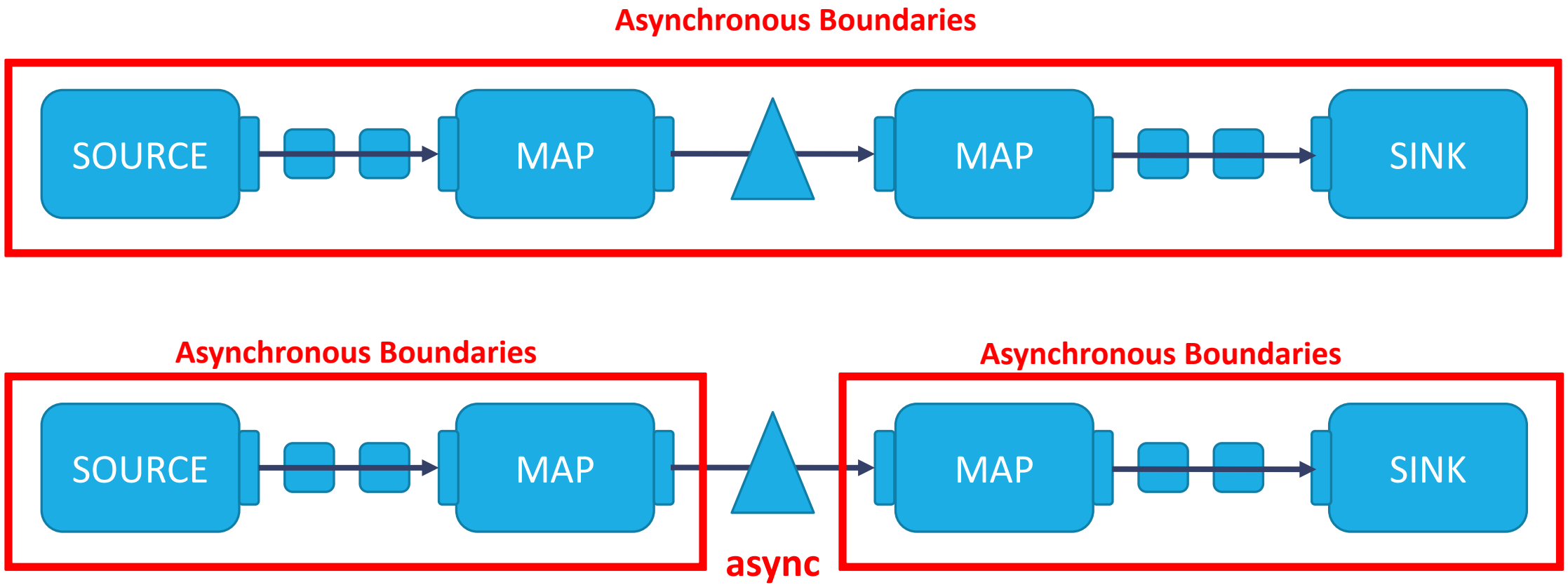
```
let spin (value: int) =
    let start = DateTime.Now.Ticks
    while DateTime.Now.Ticks - start < int64 value do
        Thread.Yield() |> ignore
    value

let count = 3000
```

```
let runSync() =
    Source.ofList [1..count]
    |> Source.map(spin)
    |> Source.map(spin)
    |> Source.runWith materializer Sink.ignore
```

Async Boundaries

```
let runAsync() =
    Source.ofList [1..count]
    |> Source.map(spin)
    |> Source.async
    |> Source.map(spin)
    |> Source.async
    |> Source.runWith materializer Sink.ignore
```

Async Boundaries



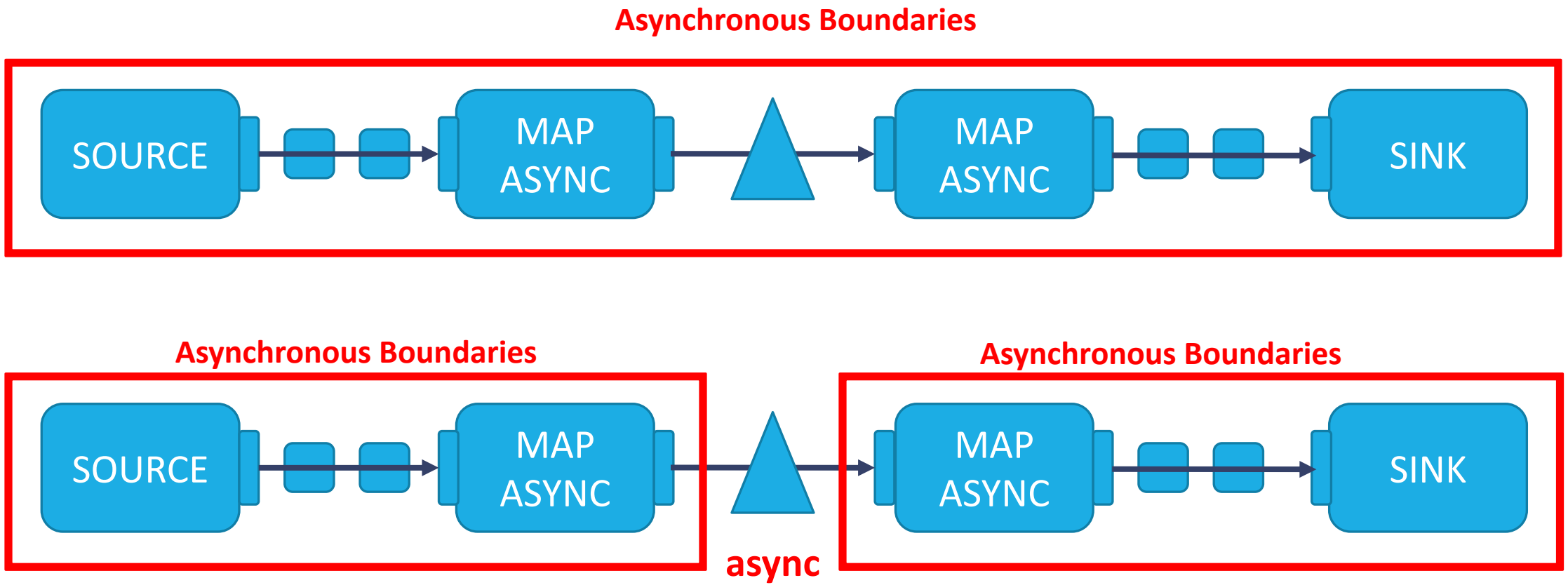
Async Boundaries & Concurrency

```
let spawn f x = async { return! f x }

let runParallelAsync() =
        Source.ofList [1..count]
        |> Source.asyncMap 1 (fun i -> spawn spin i)
        |> Source.asyncMap 1 (fun i -> spawn spin i)
        |> Source.runWith materializer Sink.ignore
```

Async Boundaries & Concurrency

```
let runAsyncParallel () =
        let n = 4
        Source.ofList [1..count]
        |> Source.asyncMap n (fun i -> spawn spin i)
        |> Source.asyncMap n (fun i -> spawn spin i)
        |> Source.runWith materializer Sink.ignore
```

Async Boundaries & Concurrency understanding AsyncMap



Async Boundaries & Concurrency

```
let runAsyncParallel () =
        let n = 4
        Source.ofList [1..count]
        |> Source.asyncMap n (fun i -> spawn spin i)
        |> Source.asyncMap n (fun i -> spawn spin i)
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```
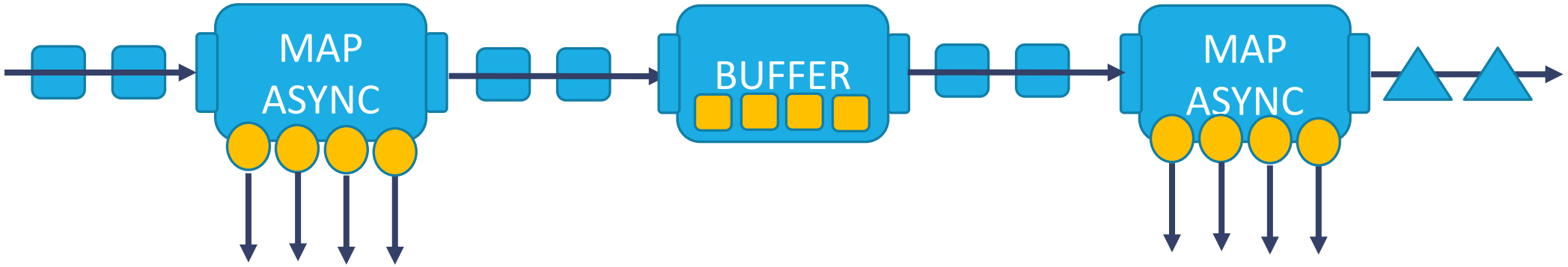

Async Boundaries & Concurrency understanding AsyncMap

```
let runAsyncParallel () =
        let n = 4
        Source.ofList [1..count]
        |> Source.asyncMap n (fun i -> spawn spin i)
        |> Source.async
        |> Source.asyncMap n (fun i -> spawn spin i)
        |> Source.async
        |> Source.runWith materializer Sink.ignore
```

Async Boundaries & Concurrency understanding AsyncMap



Buffer for improving performance

```
let runAsyncParallelBuffer () =
    let n = 4
    Source.ofList [1..count]
    |> Source.asyncMap n (fun i -> spawn spin i)
    |> Source.buffer 16 OverflowStrategy.Backpressure
    |> Source.asyncMap n (fun i -> spawn spin i)
    |> Source.buffer 16 OverflowStrategy.Backpressure
    |> Source.runWith materializer Sink.ignore
```

Batching Stream Events

```
let updateSink =
    Sink.ForEach<ITweet * MarkerLocation list>(fun (tweet, emotions) ->
    agentUpdate.Post emotions // update UI
    )

tweetSource
|> Source.map sentimentAnalysis
|> Source.map coordinateFlow
|> Source.grouped 100
// |> Source.groupedWithin 100 TimeSpan.FromSeconds(15.)
|> Source.runWith updateSink
```

Throttling

```
tweetSource
|> Source.map sentimentAnalysis
|> Source.map coordinateFlow
|> Source.grouped 100
|> Source.throttle ThrottleMode.Shaping 10  TimeSpan.FromSeconds(1.)
|> Source.runWith updateSink
```

Summary

The Benefits (And Limitations) Of Reactive Programming

- Reactive Streams can be easily composed to construct sophisticated, reliable, and resilient systems
- Akka Streams are powerful and natural for constructing streaming-data systems processing
- To perform tasks concurrently in Reactive Stream use multi-threaded patterns such as Batching, Asynchronous boundaries and Throttling

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