Reactive Architectures

Succeeding with Reactive Architectures

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Who are you?

I am a polyglot coding architect with over 20 years of experience delivering solutions in government, healthcare, and finance and ecommerce. During that time I have worked for the DTI, Reuters, Sungard, Misys, Beazley, Huddle and Just Eat Takeaway delivering everything from bespoke enterprise solutions, 'shrink-wrapped' products for thousands of customers, to SaaS applications for hundreds of thousands of customers.

I am an experienced systems architect with a strong knowledge of OO, TDD/BDD, DDD, EDA, CQRS/ES, REST, Messaging, Design Patterns, Architectural Styles, ATAM, and Agile Engineering Practices

I am frequent contributor to OSS, and I am the owner of: https://github.com/BrighterCommand. I speak regularly at user groups and conferences around the world on architecture and software craftsmanship. I run public workshops teaching messaging, event-driven and reactive architectures.

I have a strong background in C#. I spent years in the C++ trenches. I dabble in Go, Java, JavaScript and Python.

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BRIGHTER

HOME INTRO TUTORIALS CONCEPTS DOCS

Welcome to Brighter

This project is a Command Processor & Dispatcher implementation with support for task queues that can be used as a lightweight library.

It can be used for implementing Ports and Adapters and CQRS (PDF) architectural styles in .NET.

It can also be used in microservices architectures for decoupled communication between the services

GET STARTED

The Reactive Manifesto

Published on September 16 2014. (v2.0)

Organisations working in disparate domains are independently discovering patterns for building software that look the same. These systems are more robust, more resilient, more flexible and better positioned to meet modern demands.

These changes are happening because application requirements have changed dramatically in recent years. Only a few years ago a large application had tens of servers, seconds of response time, hours of offline maintenance and gigabytes of data. Today applications are deployed on everything from mobile devices to cloud-based clusters running thousands of multi-core processors. Users expect millisecond response times and 100% uptime. Data is measured in Petabytes. Today's demands are simply not met by yesterday's software architectures.

We believe that a coherent approach to systems architecture is needed, and we believe that all necessary aspects are already recognised individually: we want systems that are Responsive, Resilient, Elastic and Message Driven. We call these Reactive Systems.

Systems built as Reactive Systems are more flexible, loosely-coupled and scalable. This makes them easier to develop and amenable to change. They are significantly more tolerant of failure and when failure does occur they meet it with elegance rather than disaster. Reactive Systems are highly responsive, giving users effective interactive feedback.

Reactive Systems are:

Responsive: The system responds in a timely manner if at all possible. Responsiveness is the cornerstone of usability and utility, but more than that, responsiveness means that problems may be detected quickly and dealt with effectively. Responsive systems focus on providing rapid and consistent response times, establishing reliable upper bounds so they deliver a consistent quality of service. This consistent behaviour in turn simplifies error handling, builds end user confidence, and encourages further interaction.

Resilient: The system stays responsive in the face of failure. This applies not only to highly-available, mission-critical systems — any system that is not resilient will be unresponsive after a failure. Resilience is achieved by replication, containment, isolation and delegation. Failures are contained within each component, isolating components from each other and thereby ensuring that parts of the system can fail and recover without compromising the system as a whole. Recovery of each component is delegated to another (external) component and high-availability is ensured by replication where necessary. The client of a component is not burdened with handling its failures.

Elastic: The system stays responsive under varying workload. Reactive Systems can react to changes in the input rate by increasing or decreasing the resources allocated to service these inputs. This implies designs that have no contention points or central bottlenecks, resulting in the ability to shard or replicate components and distribute inputs among them. Reactive Systems support predictive, as well as Reactive, scaling algorithms by providing relevant live performance measures. They achieve elasticity in a cost-effective way on commodity hardware and software platforms.

Message Driven: Reactive Systems rely on asynchronous message-passing to establish a boundary between components that ensures loose coupling, isolation and location transparency. This boundary also provides the means to delegate failures as messages. Employing explicit message-passing enables load management, elasticity, and flow control by shaping and monitoring the message queues in the system and applying back-pressure when necessary. Location transparent messaging as a means of communication makes it possible for the management of failure to work with the same constructs and semantics across a cluster or within a single host. Non-blocking communication allows recipients to only consume resources while active, leading to less system overhead.

Large systems are composed of smaller ones and therefore depend on the Reactive properties of their constituents. This means that Reactive Systems apply design principles so these properties apply at all levels of scale, making them composable. The largest systems in the world rely upon architectures based on these properties and serve the needs of billions of people daily. It is time to apply these design principles consciously from the start instead of rediscovering them each time.

The Reactive Manifesto

Published in September 2014
Author(s): Jonas Bonér (Erik Meijer, Martin Odersky, Greg Young, Martin Thompson, Roland Kuhn, James Ward and Guillaume Bort)

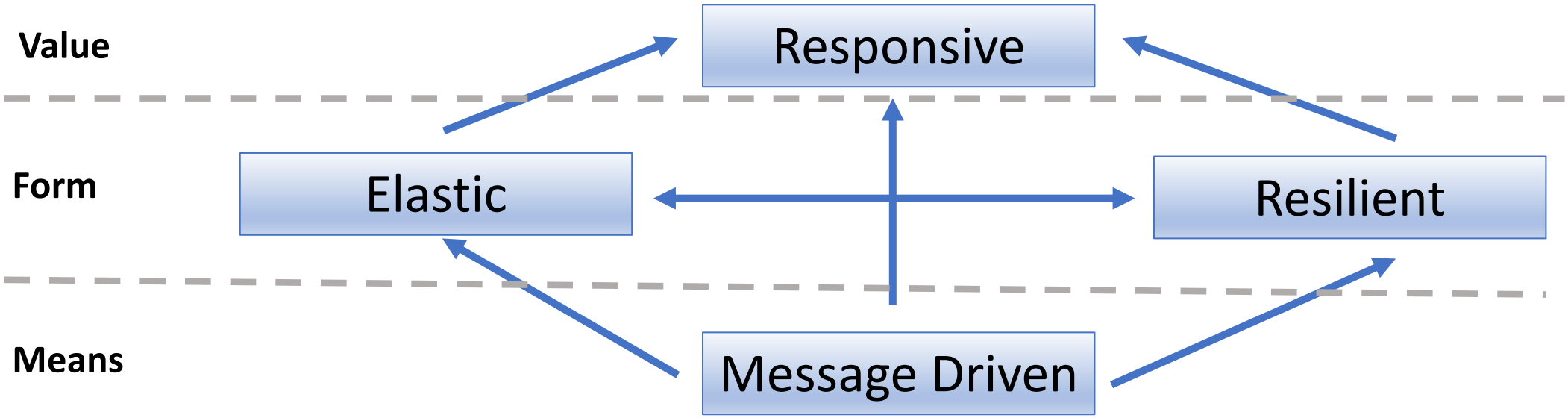
Defines an architectural style: **Reactive Applications**

Write applications that:

- *react to events*: the event-driven nature enables the following qualities
- *react to load*: focus on scalability rather than single-user performance
- *react to failure*: resilient systems with the ability to recover at all levels
- *react to users*: combine the above for an interactive user experience

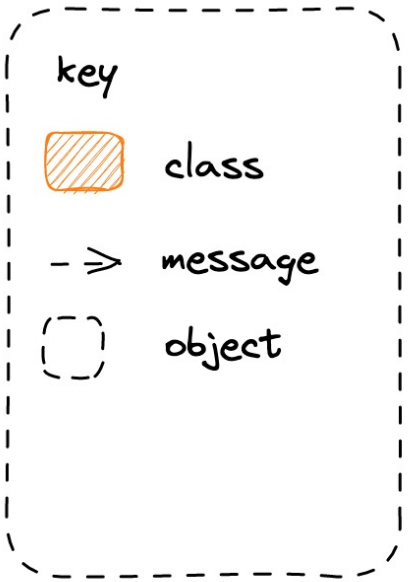
Responsive: The system responds in a timely manner.
Resilient: The system stays responsive in the presence of failure.
Elastic: The system stays responsive under varying workload.
Message Driven: Rely on asynchronous message passing

https://www.reactivemanifesto.org/

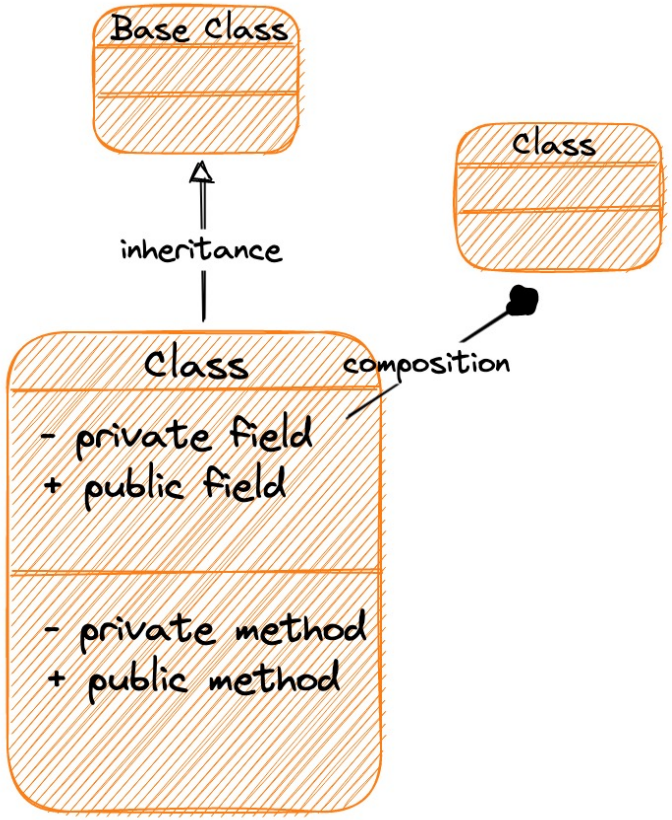

Value
Responsive
Form
Elastic
Resilient
Means
Message Driven

Agenda

- Objects
  - SOA
- Reactive
  - Reactive Programming
    - Dataflow
    - Actors
    - Flow Based Programming
    - Reactor Pattern
  - Reactive Systems
    - Message Passing
    - Resilience
    - Elasticity
    - Responsiveness



Object Orientation

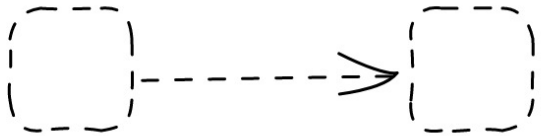


Data and Behaviour

A class couples data and the behaviour that depends upon that data. This allows encapsulation the data can be hidden and just behaviour exposed

Dynamic Dispatch

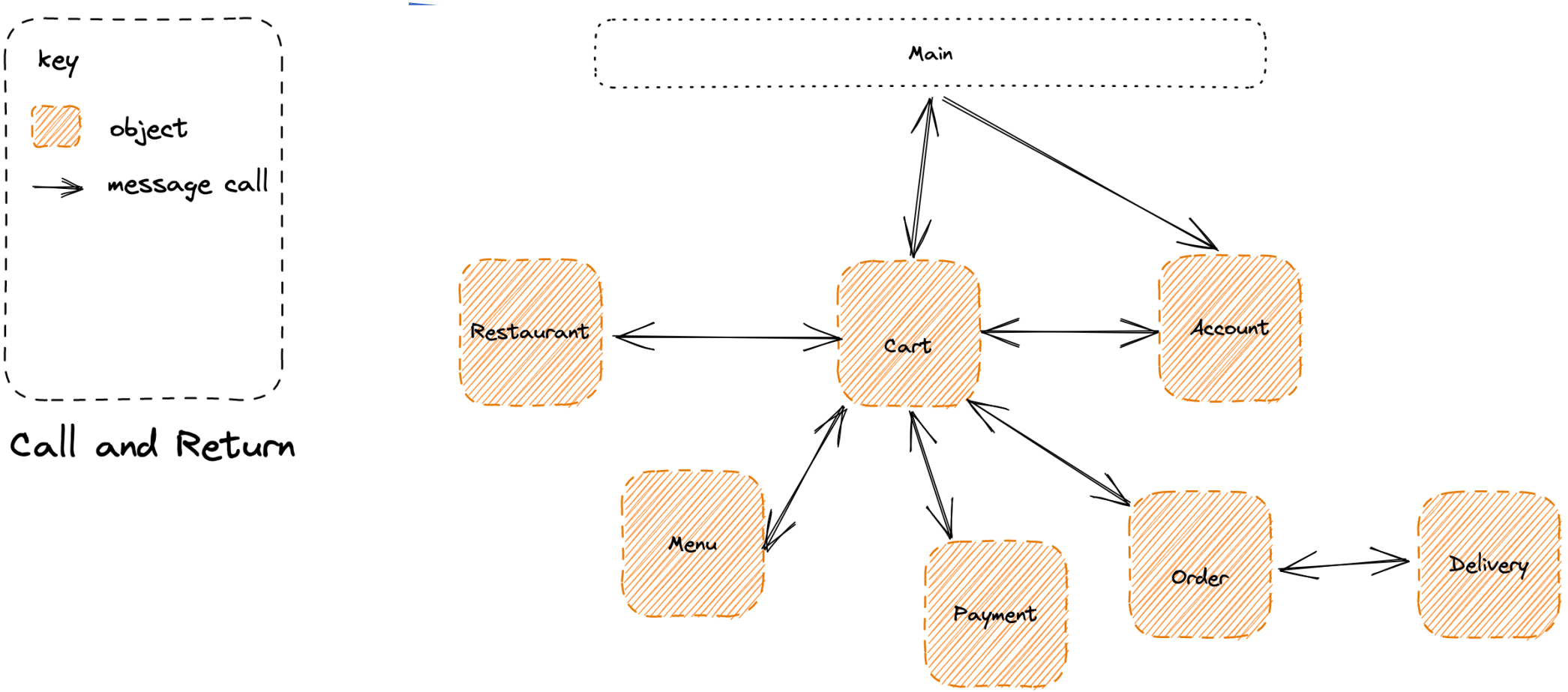
Due to inheritance the method chosen in response to a message may come from the base class of an object



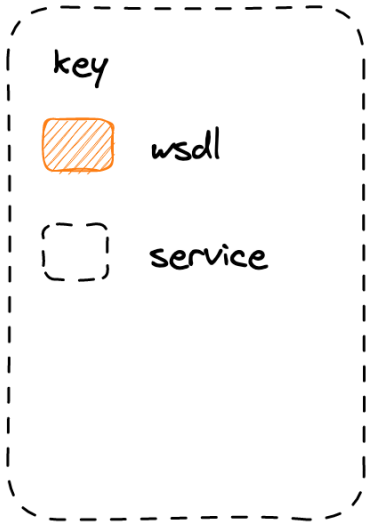
Message Passing

Objects communicate by message passing. A message is the method to call, and the parameters to that method.

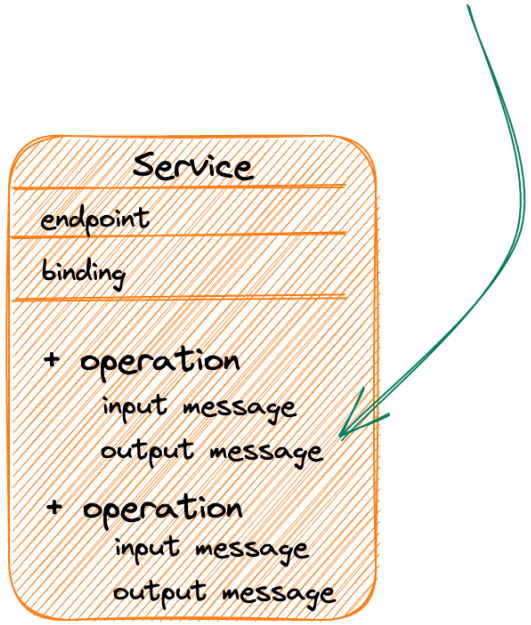
Call and Return: The main method represents our entry point and it uses message passing to invoke objects, which in turn invoke other objects, and return to their caller



God Object: A danger here is that we end up with a ”god” object, such as Cart here, that controls all the other objects. This is a high-degree of behavioral coupling

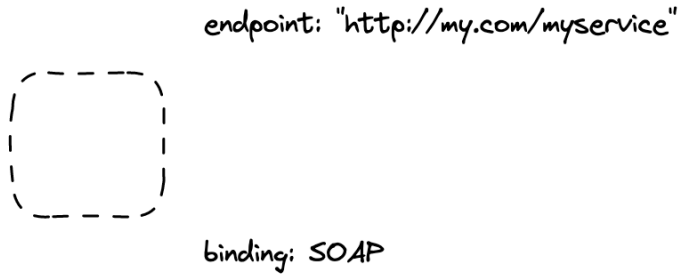


Service Orientation



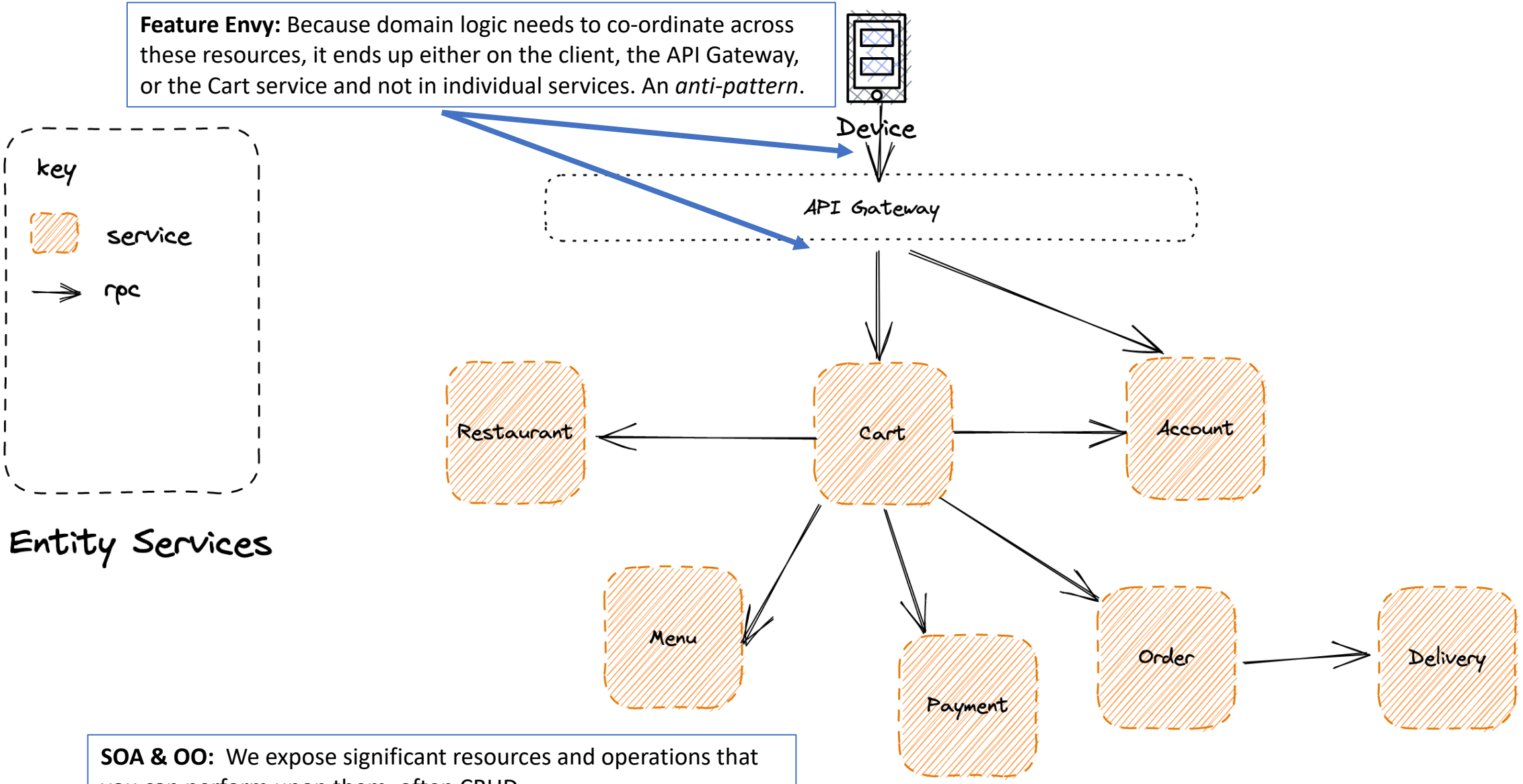
Data and Behaviour

A service couples data and the behaviour that depends upon that data. This allows encapsulation the data can be hidden and just behaviour exposed

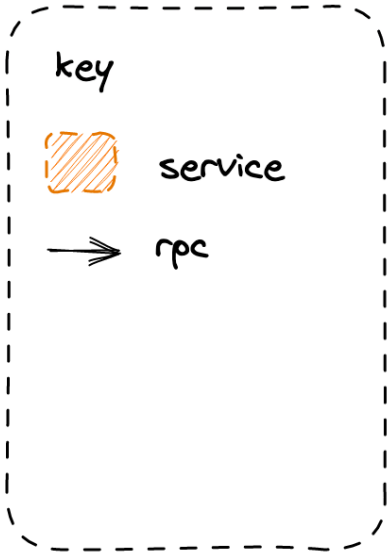


SOA & OO: SOA creates OO-like components, they encapsulate their data and expose behavior that is coupled to that data. This is the Web Services approach to services.

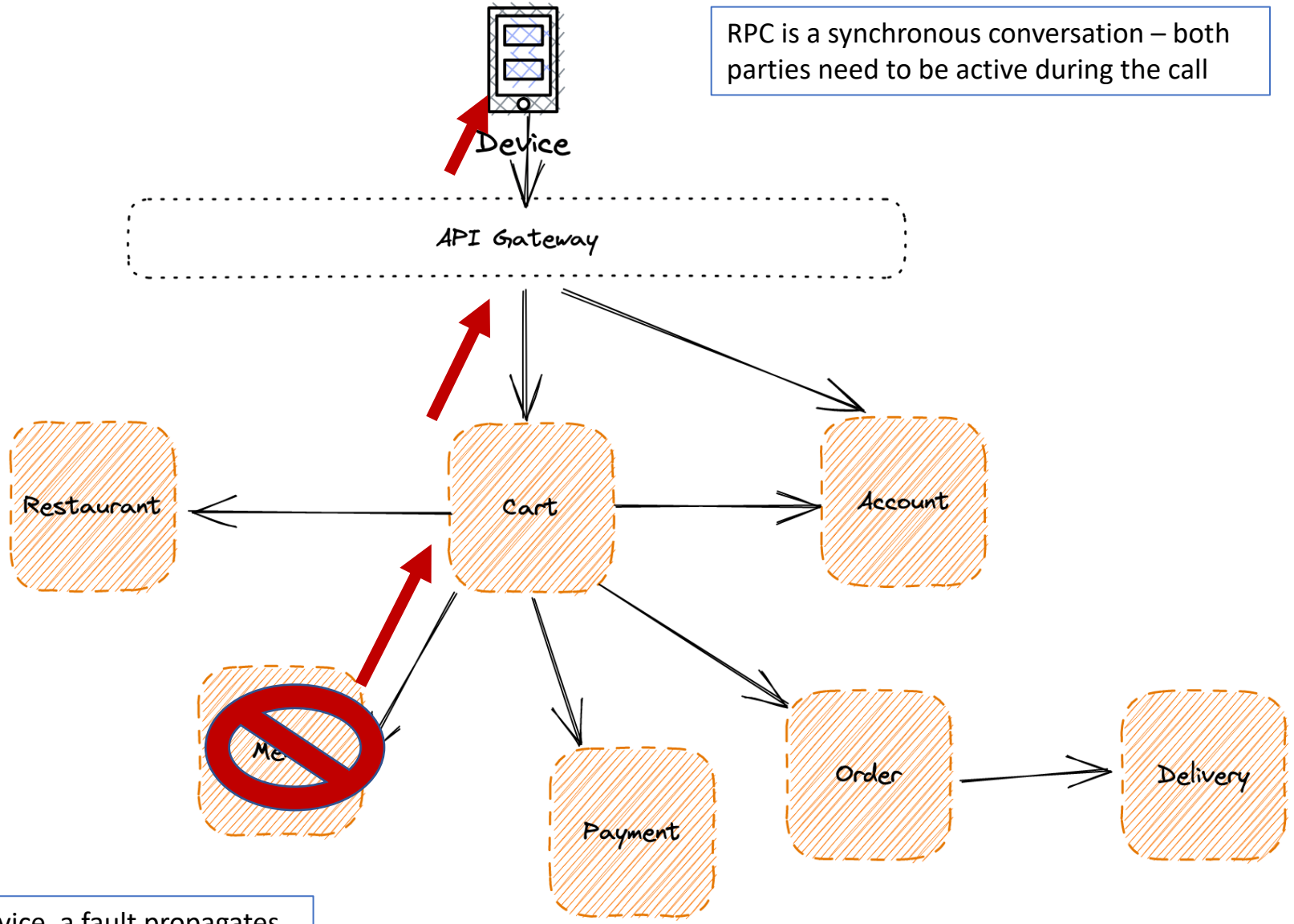
Feature Envy: Because domain logic needs to co-ordinate across these resources, it ends up either on the client, the API Gateway, or the Cart service and not in individual services. An *anti-pattern*.



SOA & OO: We expose significant resources and operations that you can perform upon them, often CRUD.



Entity Services



RPC is a synchronous conversation – both parties need to be active during the call

Faults Propagate: With a synchronous service, a fault propagates

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    - Reactor Pattern
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    - Resilience
    - Elasticity
    - Responsiveness

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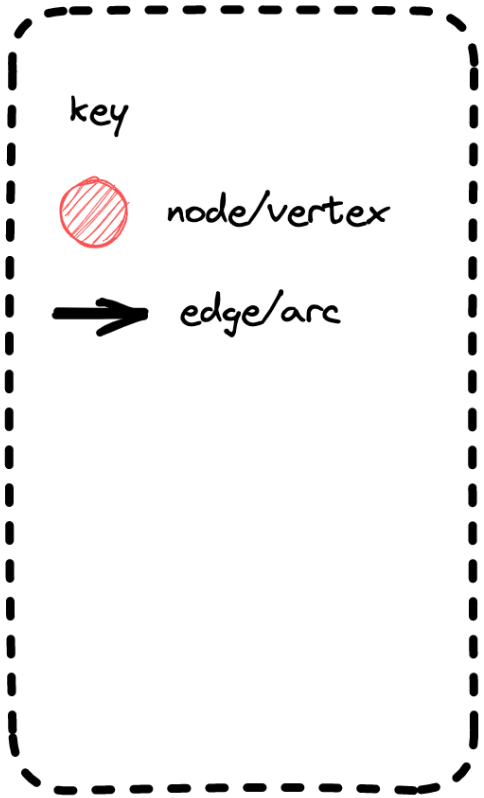
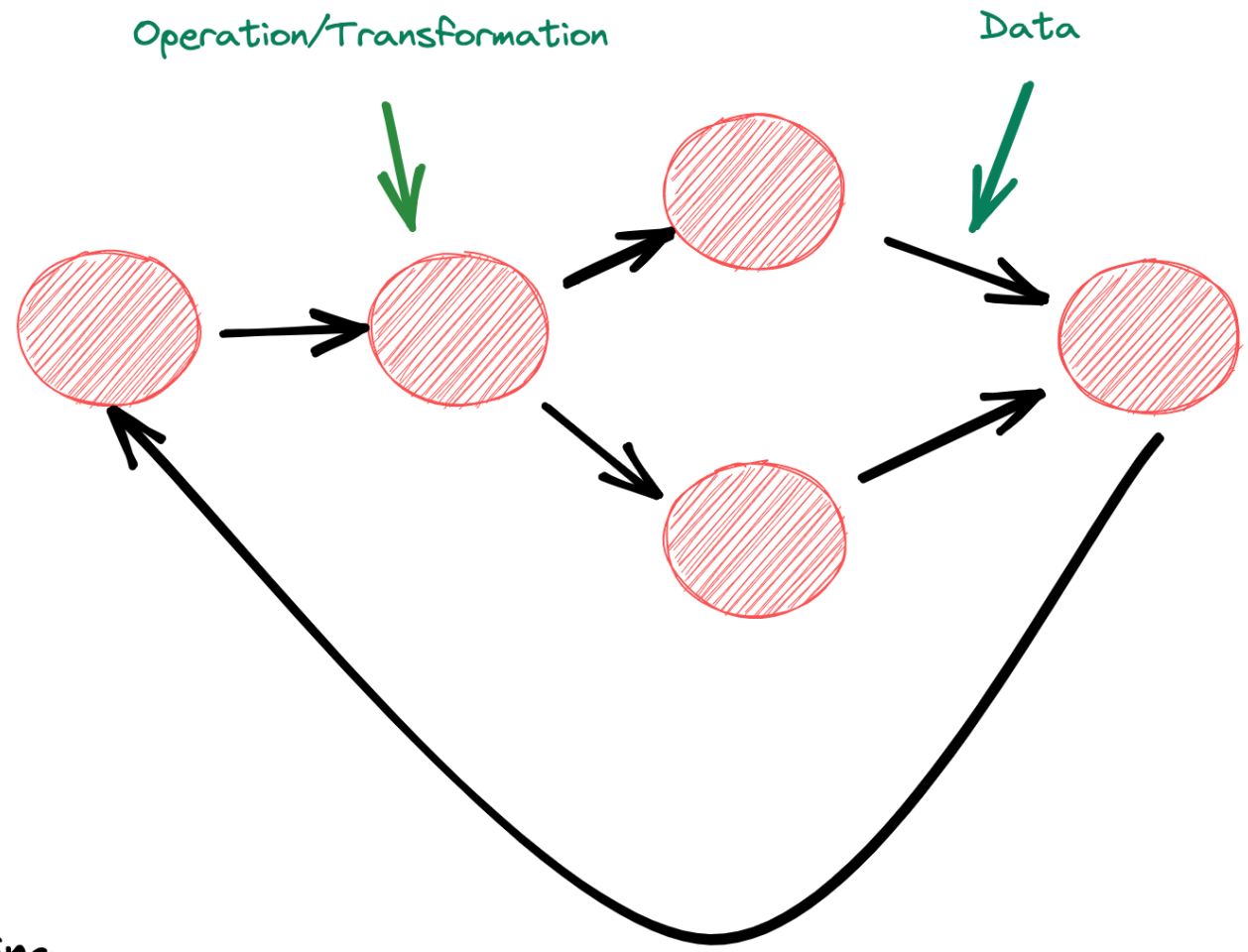


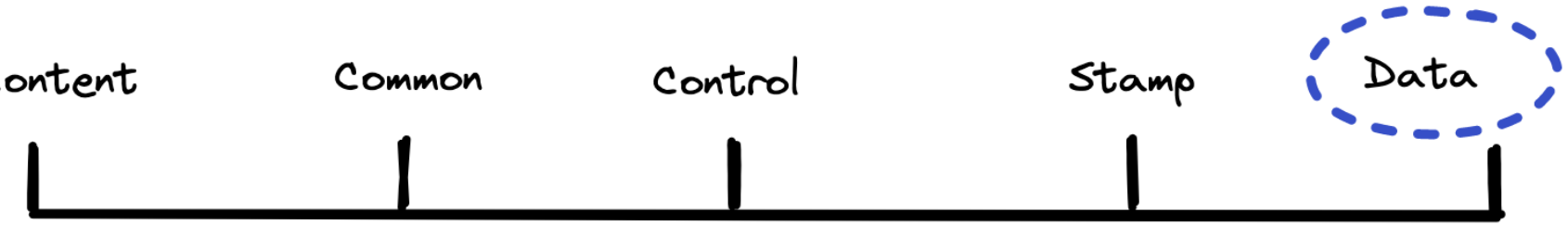


Dataflow Programming

Jack Dennis et al.

Data Flow Programming conceptualizes a program as a directed graph where operations are represented as nodes which are connected via arcs through which data flows. A node performs an operation when input data is available.

Coupling



Tight

More Interdependency

More Coordination

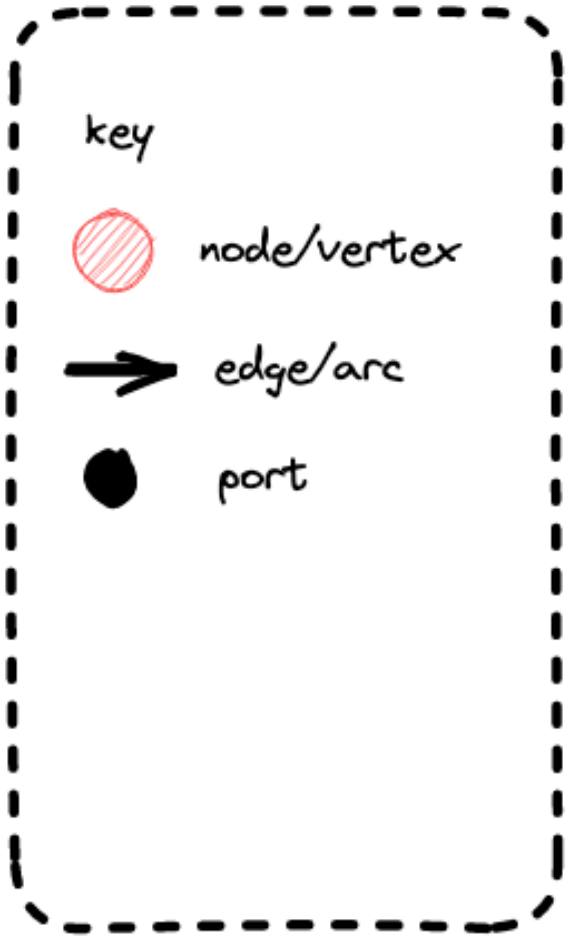
More Information Flow

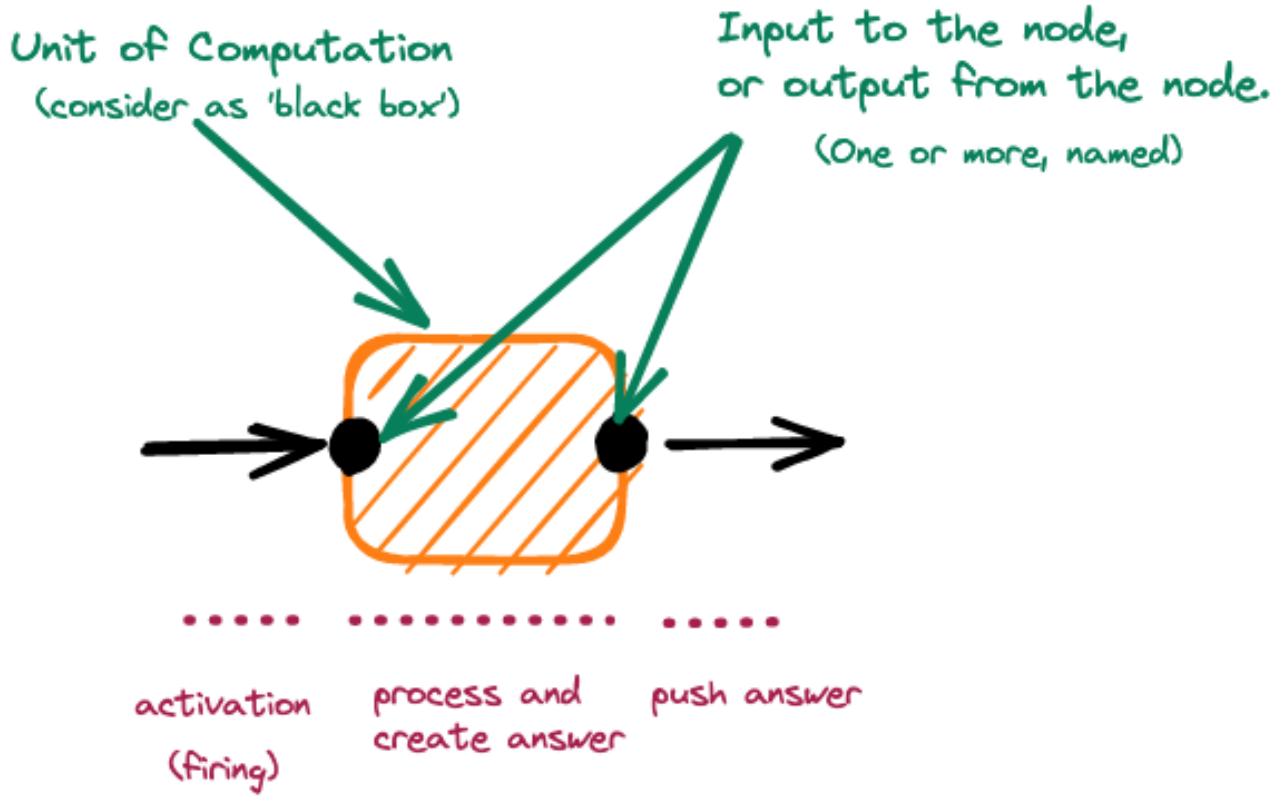
Loose

Less Interdependency

Less Coordination

Less Information Flow



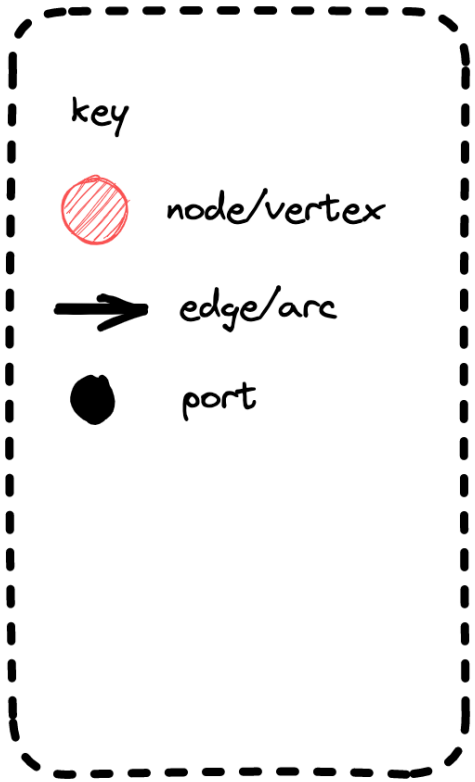


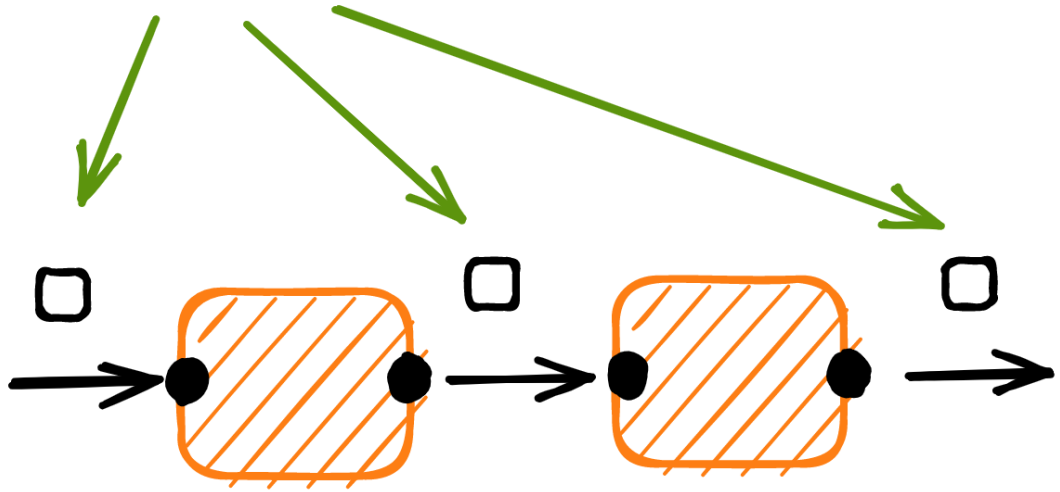
Dataflow Programming

Jack Dennis et al.

Data Packet

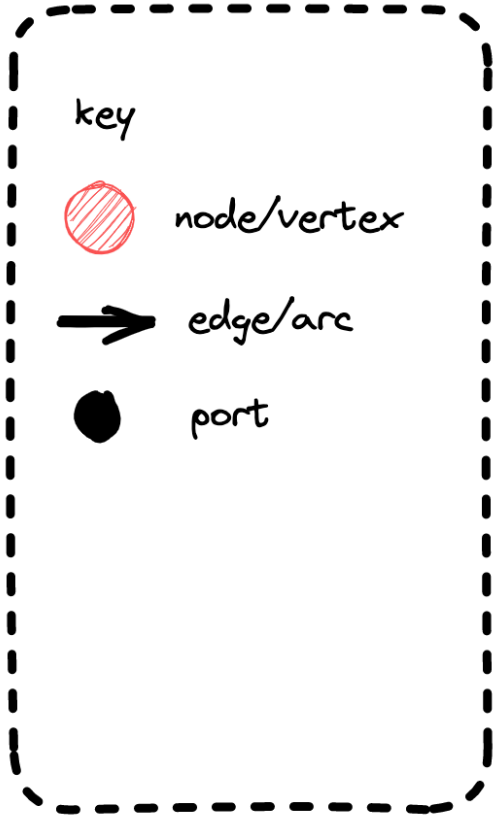
primitive/compound, structured/unstructured values, and even include other data packets

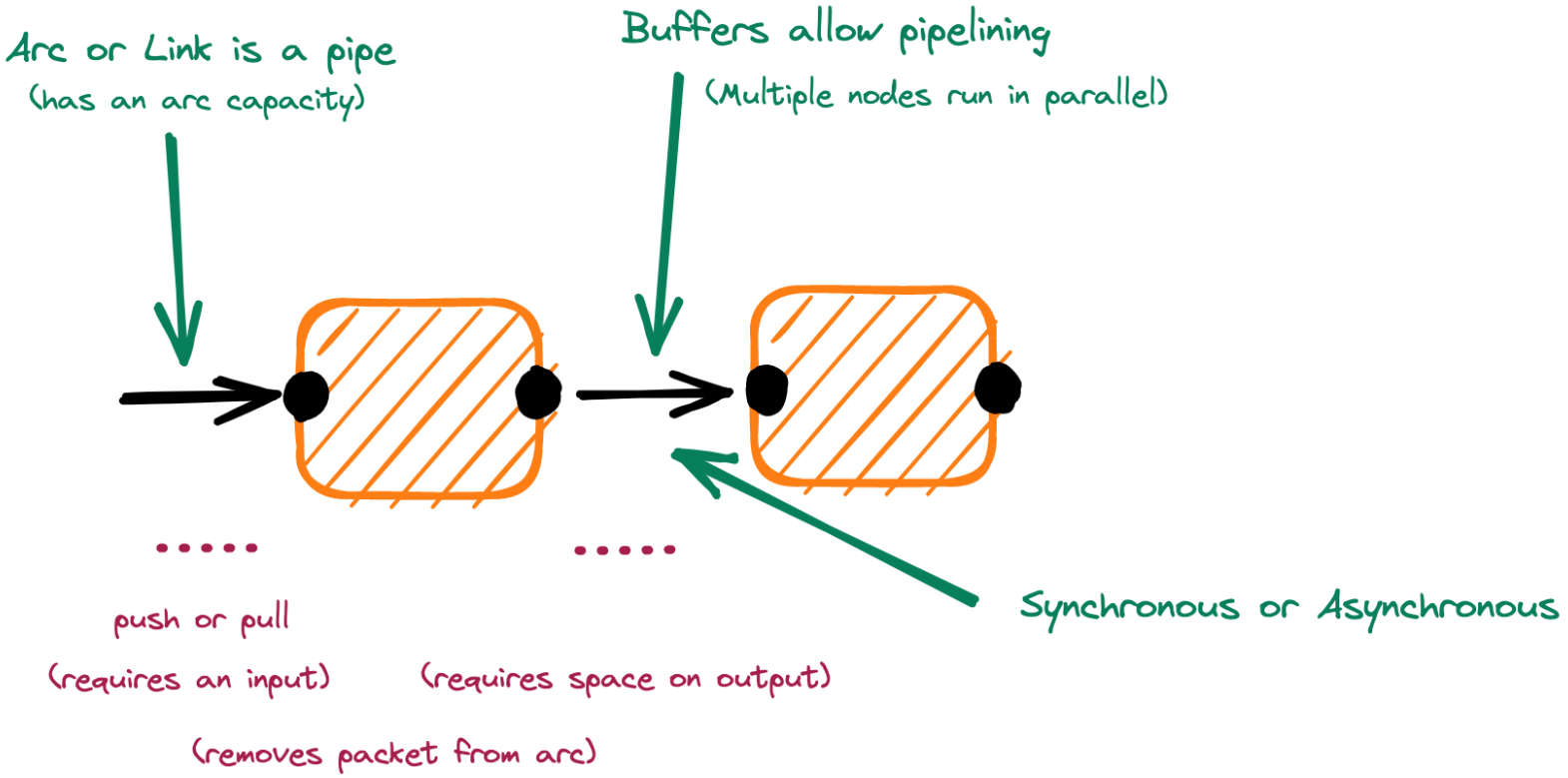




Dataflow Programming

Jack Dennis et al.





Dataflow Programming

Jack Dennis et al.

Node Lifetime: In 'classic' dataflow programming the lifetime of a node is from activation when there is work to do (push) or work is requested (pull) until it has pushed the answer.

Capacity: In dataflow programming we do not activate a node to read from the input, if there is no space on the output. (Infinite capacity links exist only in theory). This creates **backpressure**.

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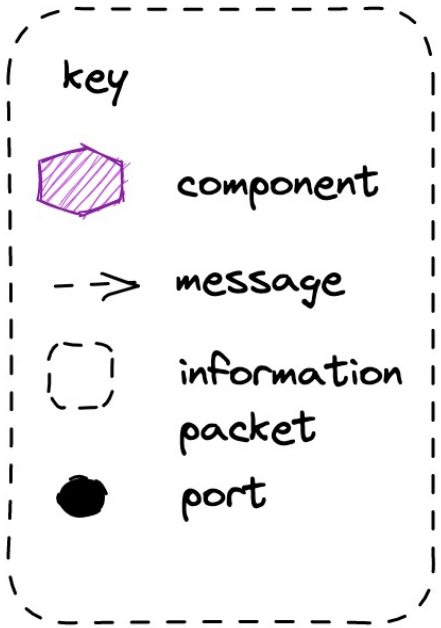
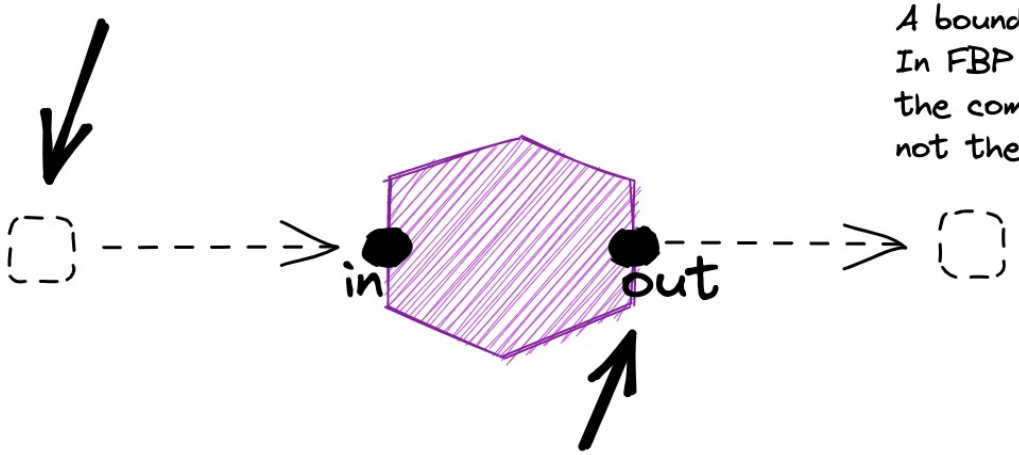
    - Responsiveness

Flow-Based Programming (FBP) is a subclass of DFP. While DFP can be synchronous or asynchronous, FBP is always asynchronous. FBP allows multiple input ports, has bounded buffers and applies back pressure when buffers fill up.



Information Packet (IP)

An independent structured piece of information with a defined lifetime.



Connector

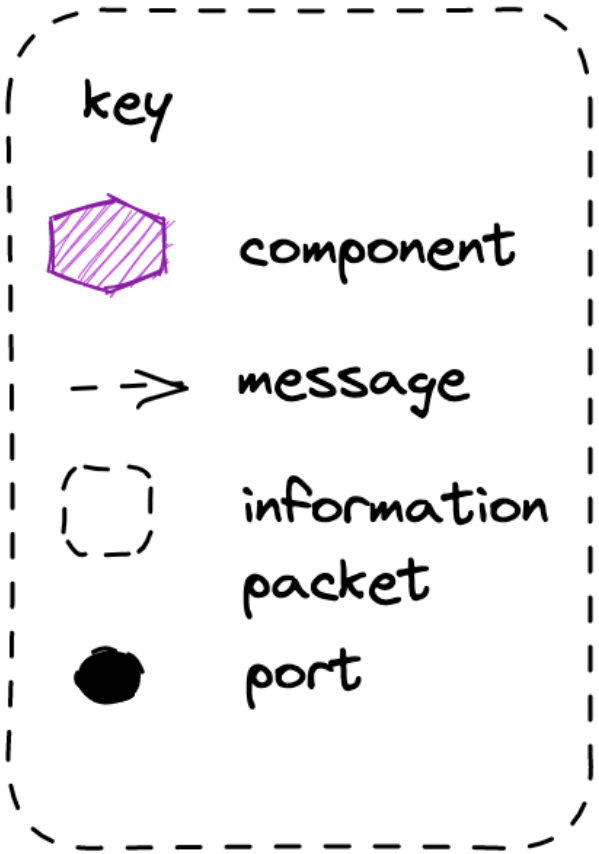
A bounded pipe of information packets. In FBP a connector is external - that is the component is only aware of the named port not the connector, so it could be swapped out

Port

The point where a connection makes contact with a process. A port is addressed by name.

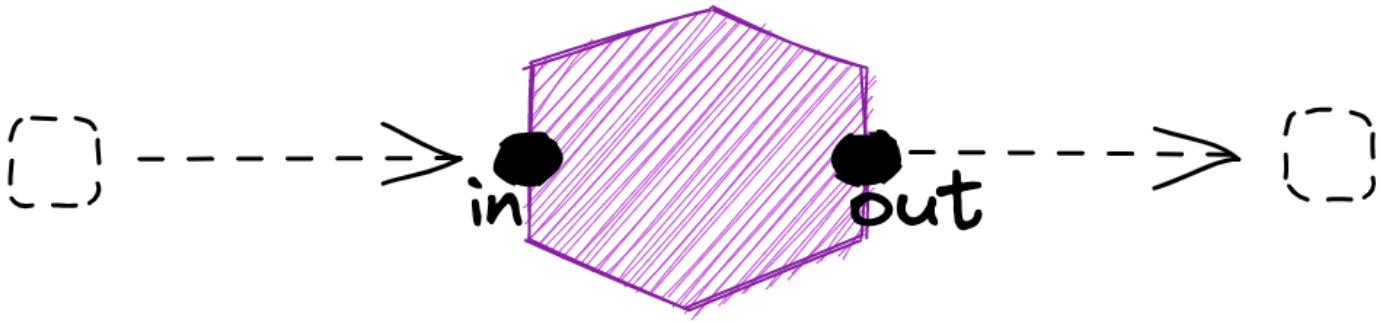
Flow Based Programming

(J. Paul Morrison)



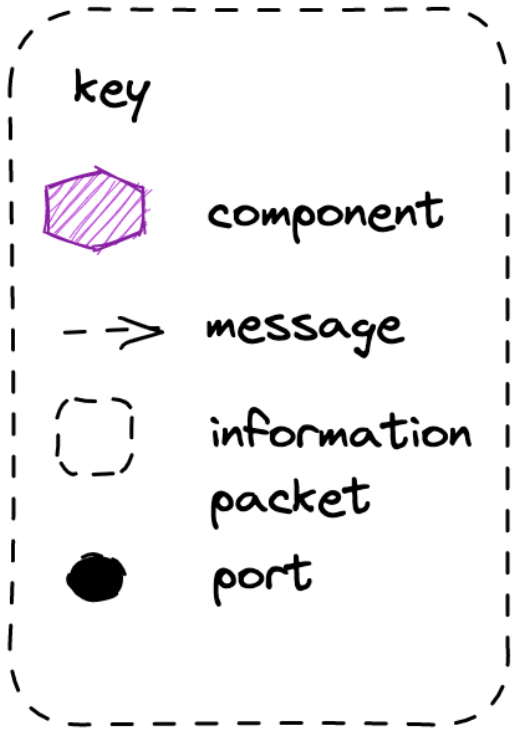
Flow Based Programming

(J. Paul Morrison)



Node Lifetime: In flow base programming the a node can remain running whilst there is work on an input queue, can can suspend instead of terminate if there is no work on its connector. **We may receive an explicit signal to indicate we should stop.**

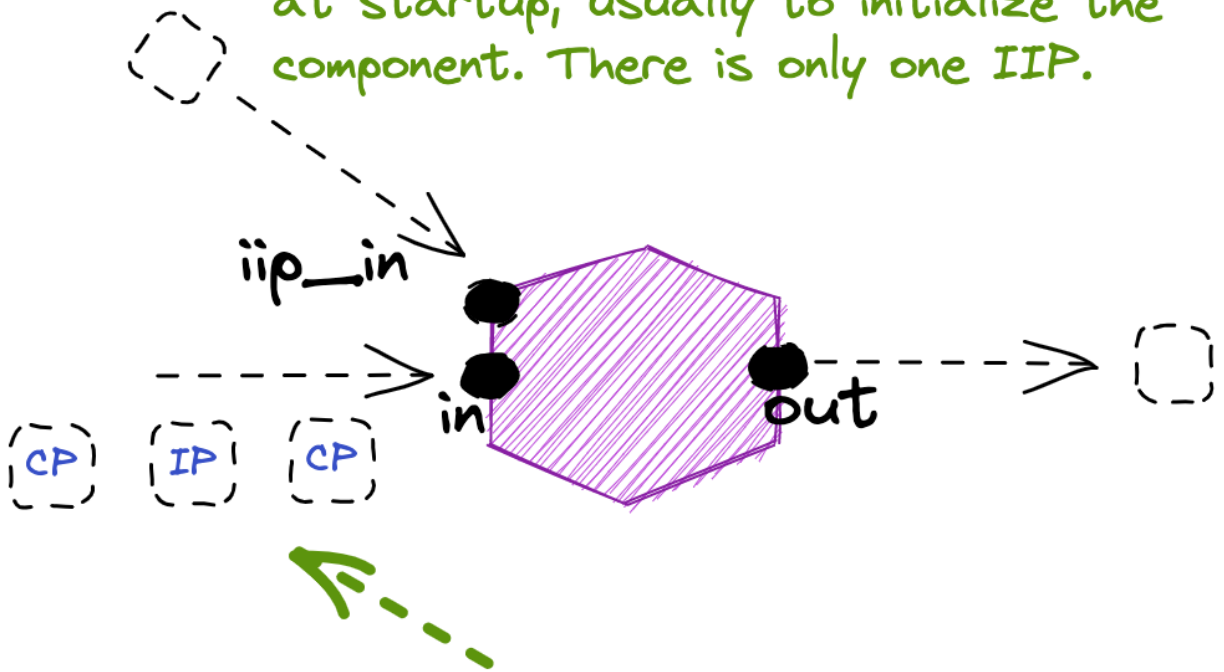
Capacity: In flow-based programming a component can test to see if it can send to out (**backpressure**), and if not decide whether to ignore (**load shedding**) or even halt.



Flow Based Programming
(J. Paul Morrison)

Initial Information Packet

A packet that the component reads at startup, usually to initialize the component. There is only one IIP.



Control Packets

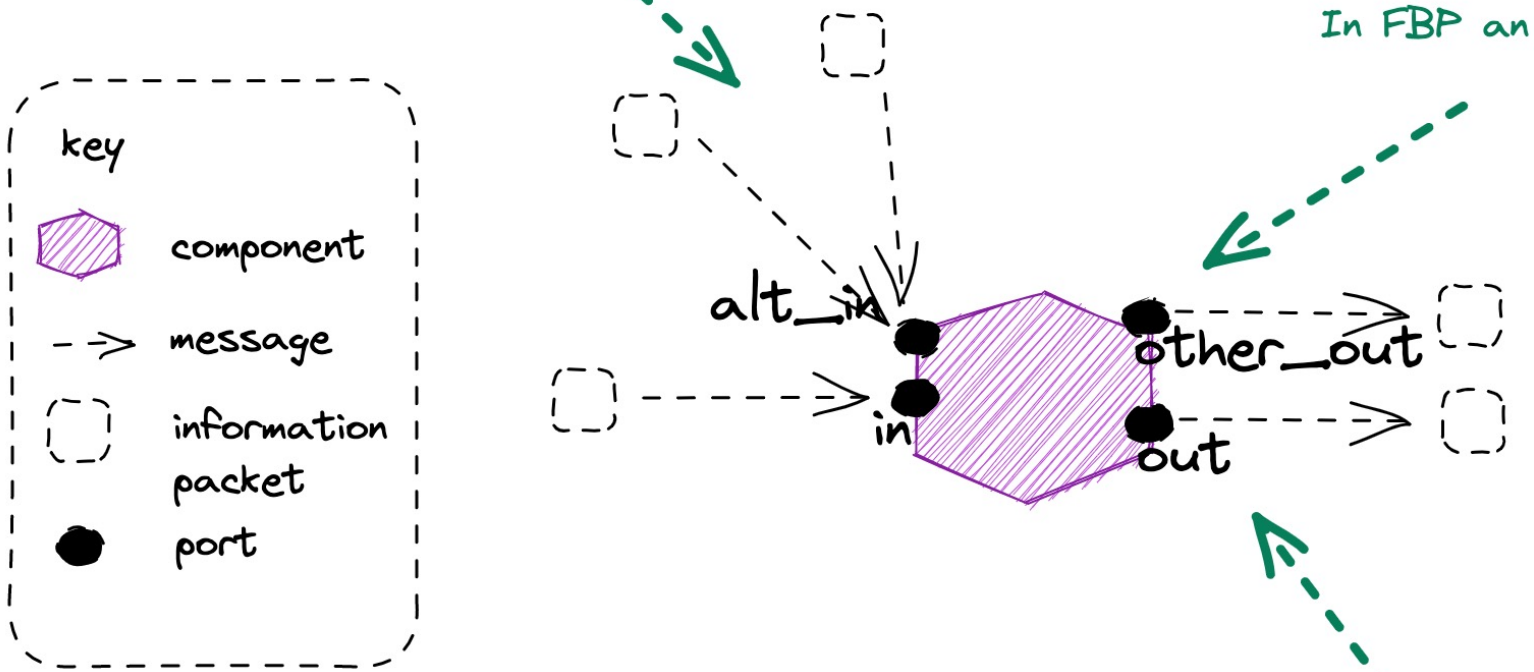
Control Packets can be used to 'bracket' groups

Multiple Writers

In FBP an in port can have multiple writers

Single Writer

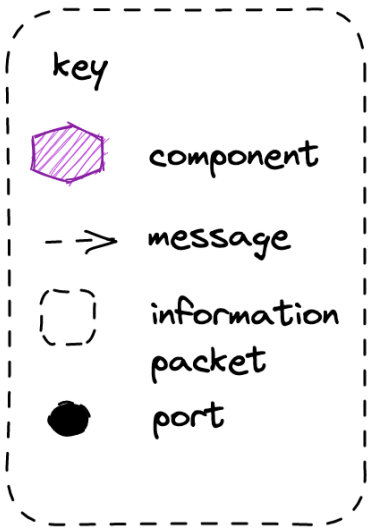
In FBP an out port is single writer



Flow Based Programming
(J. Paul Morrison)

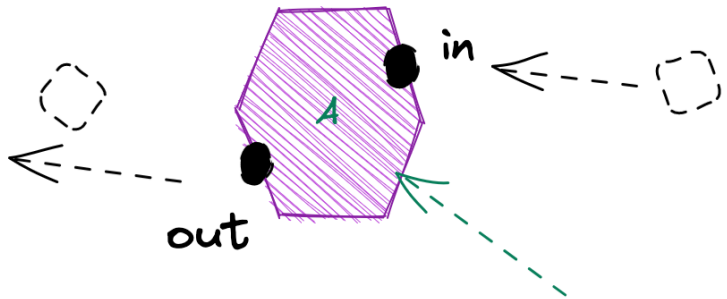
Multiple In/Out Ports

In FBP we can have multiple in or out ports

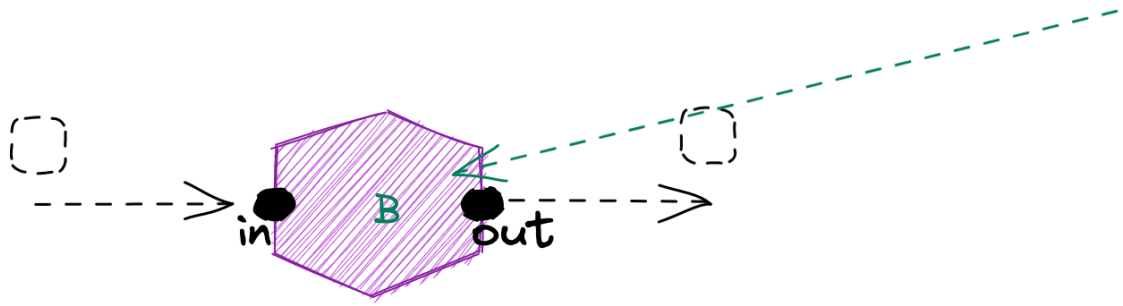


Flow Based Programming

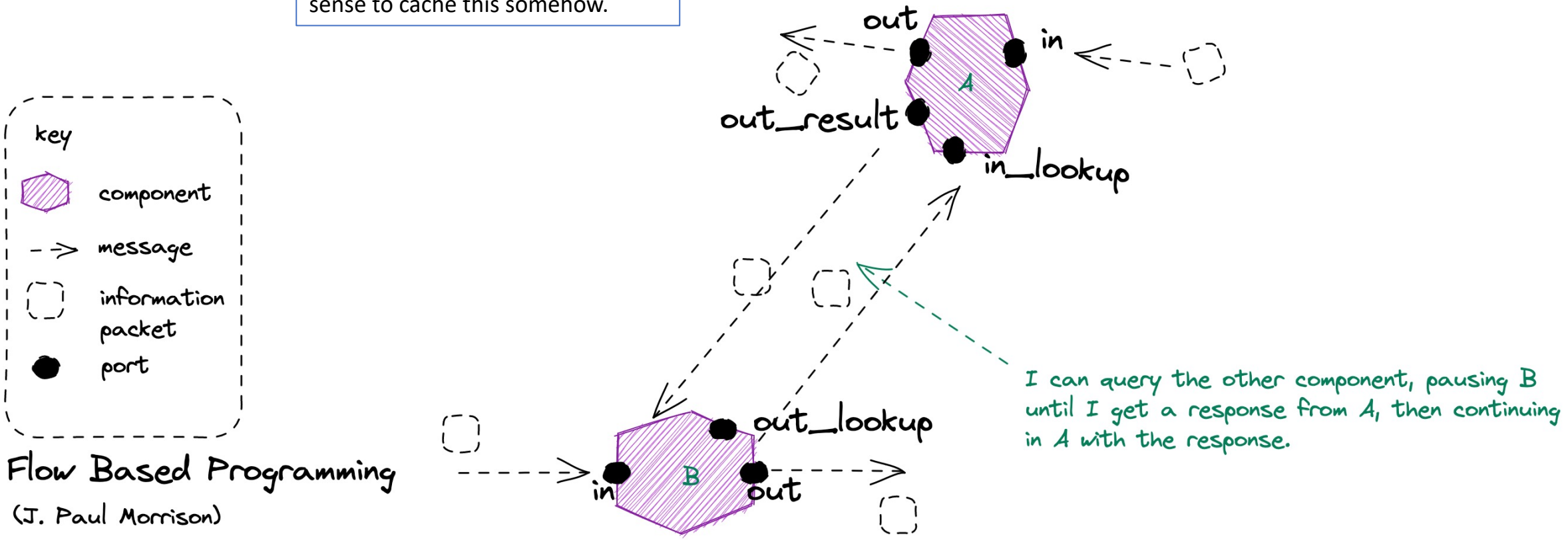
(J. Paul Morrison)

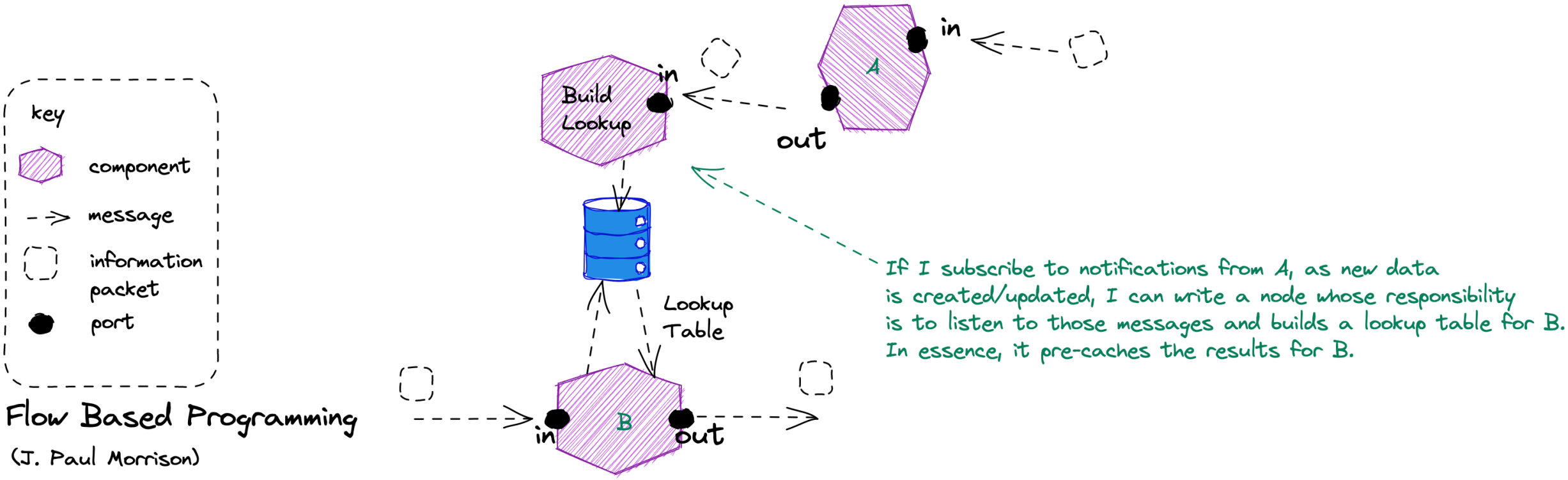


What happens if I need data from one node, to react in another node?



Walk of Shame: The trouble is that we may keep asking, so it makes sense to cache this somehow.




key
component
message
information packet
port
Flow Based Programming
(J. Paul Morrison)
Build Lookup
in
out
A
in
Lookup Table
in
B
out
If I subscribe to notifications from A, as new data is created/updated, I can write a node whose responsibility is to listen to those messages and builds a lookup table for B. In essence, it pre-caches the results for B.

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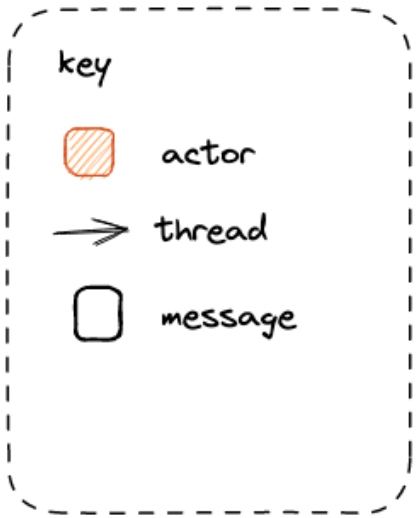
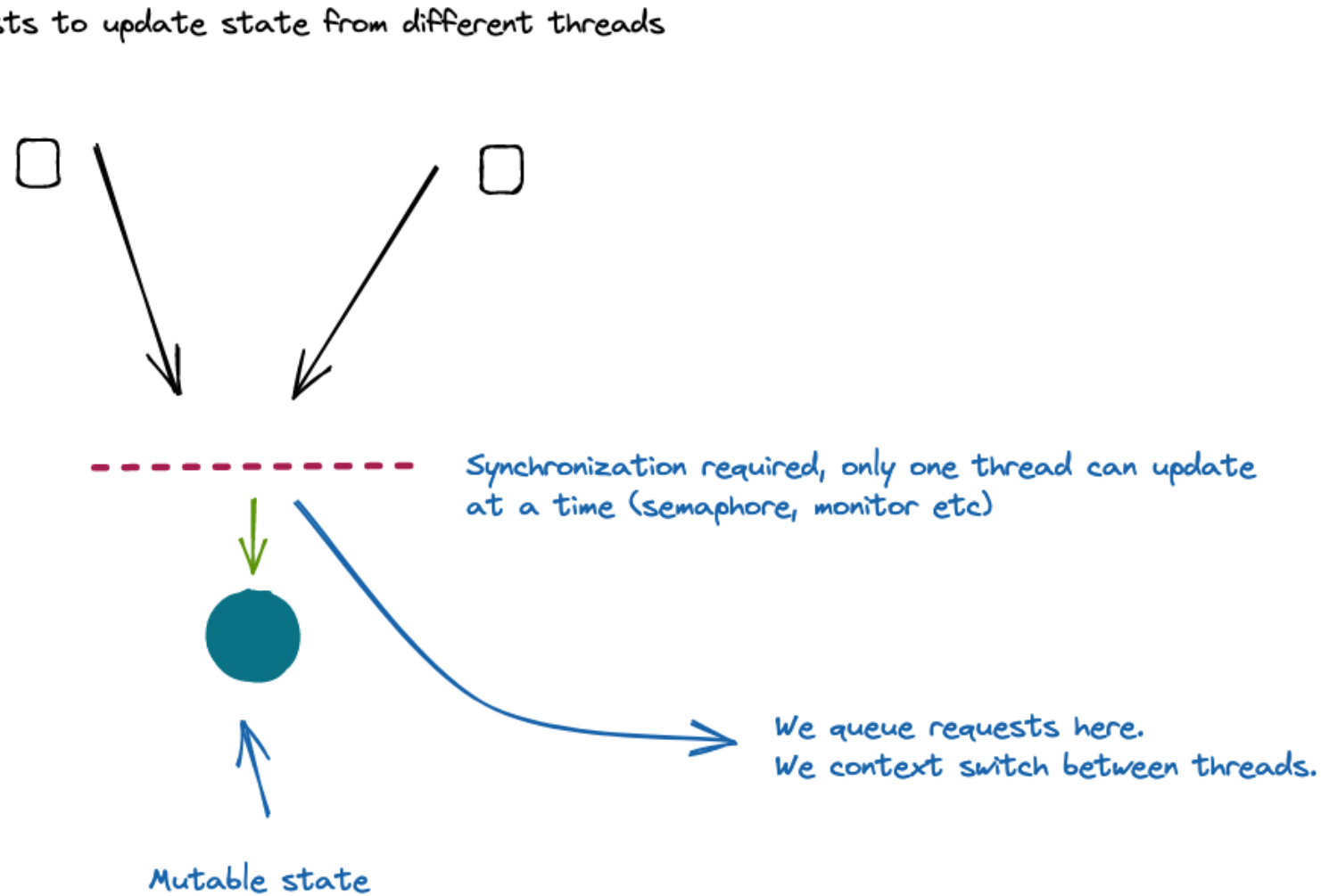
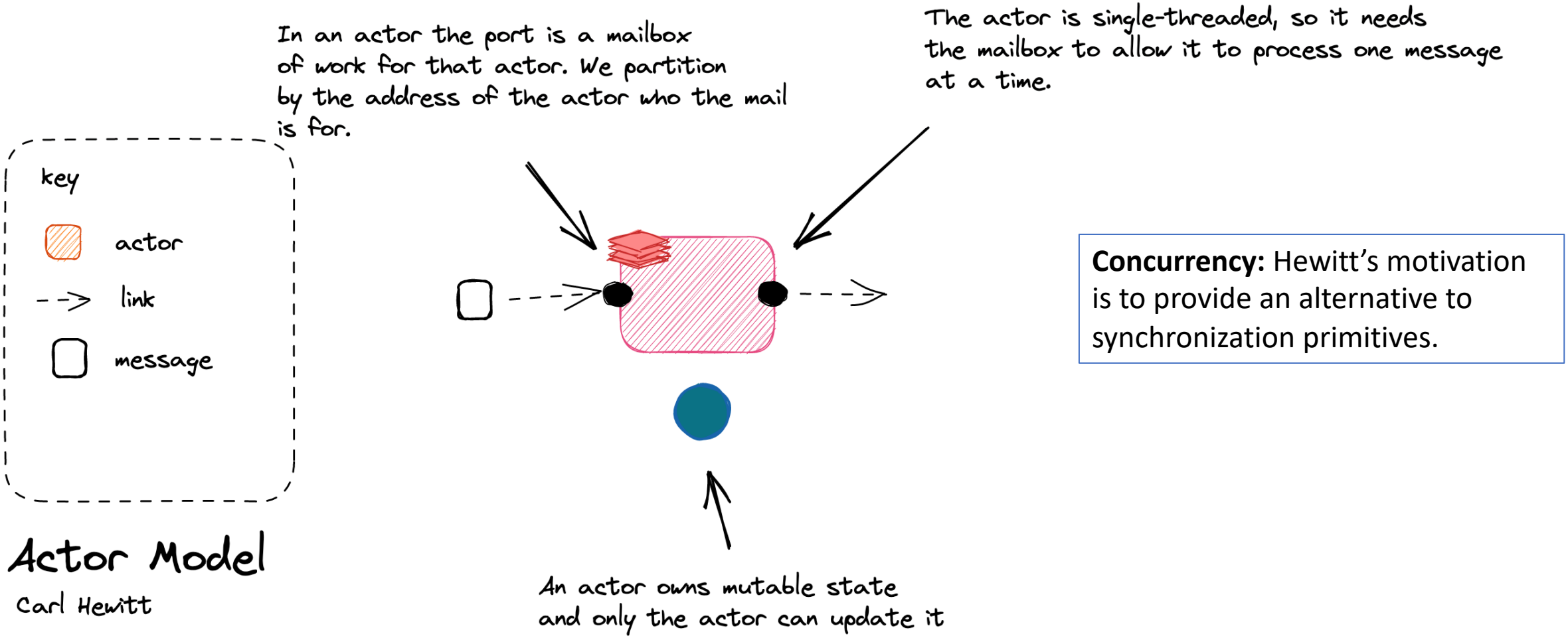


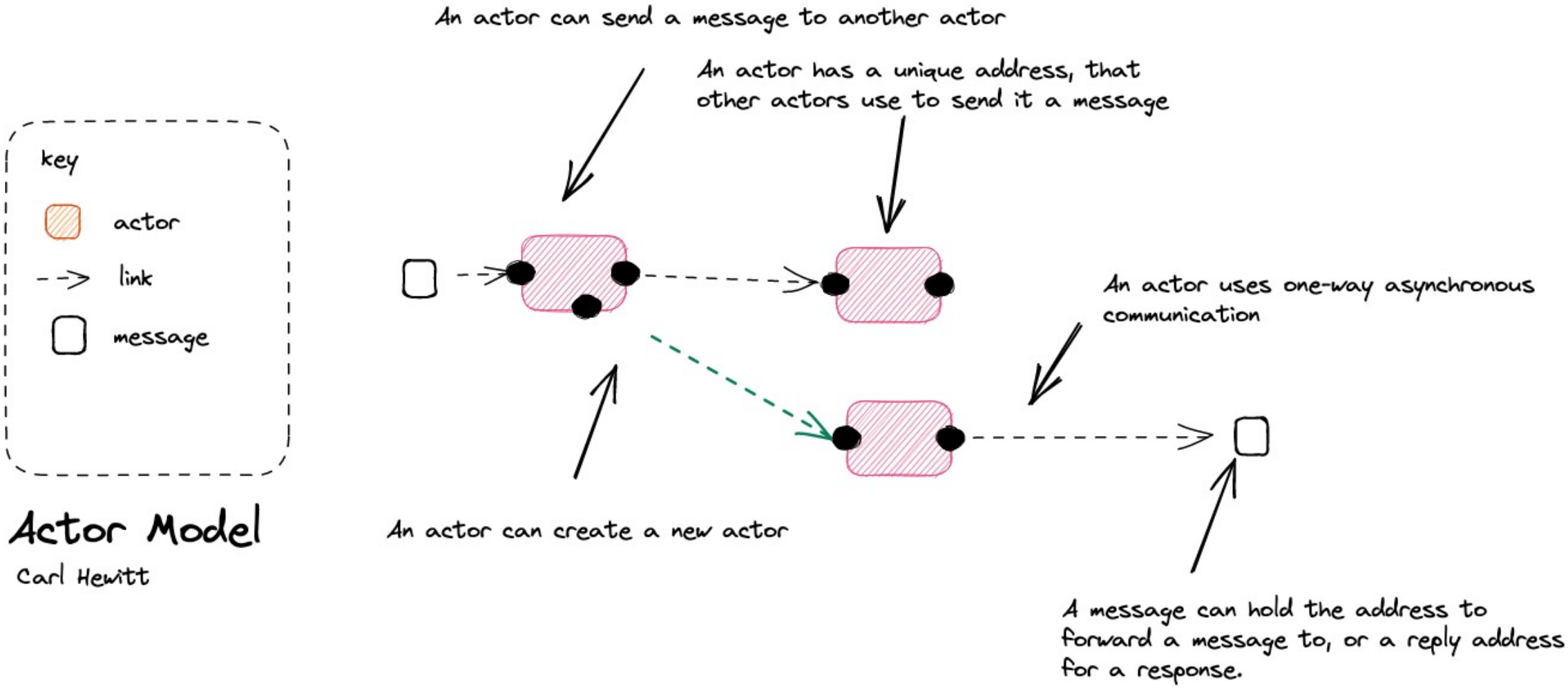
No Actors Model

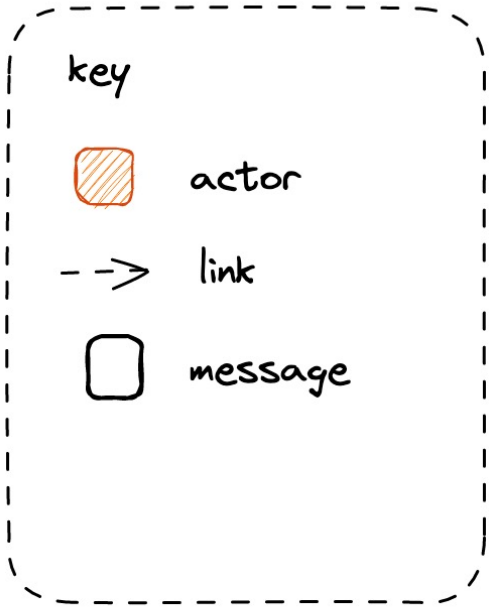
Edsger W. Dijkstra





Concurrency: Hewitt's motivation is to provide an alternative to synchronization primitives.

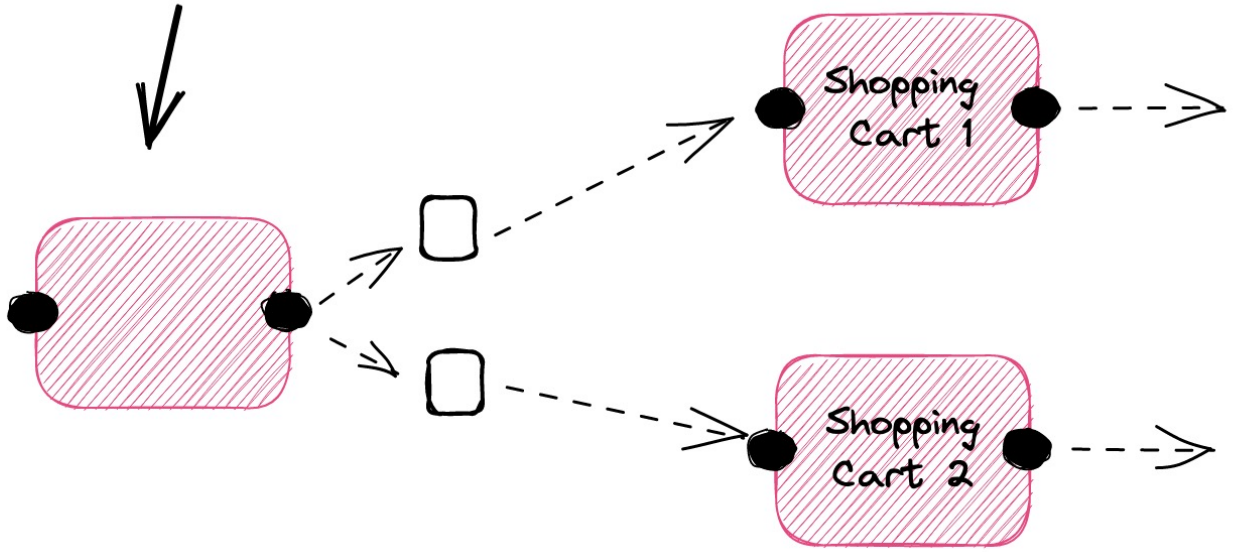

An actor can send a message to another actor
An actor has a unique address, that other actors use to send it a message
key
actor
link
message
An actor uses one-way asynchronous communication
Actor Model
Carl Hewitt
An actor can create a new actor
A message can hold the address to forward a message to, or a reply address for a response.



Actor Model

Carl Hewitt

We create child actors, so we know the address that corresponds to the state we want to send a message to



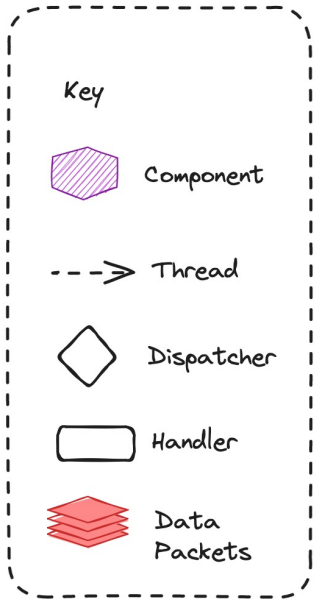
Scaling: Scaling to multiple actors requires partitioning messages for actors i.e. all messages for the same mutable to a single actor

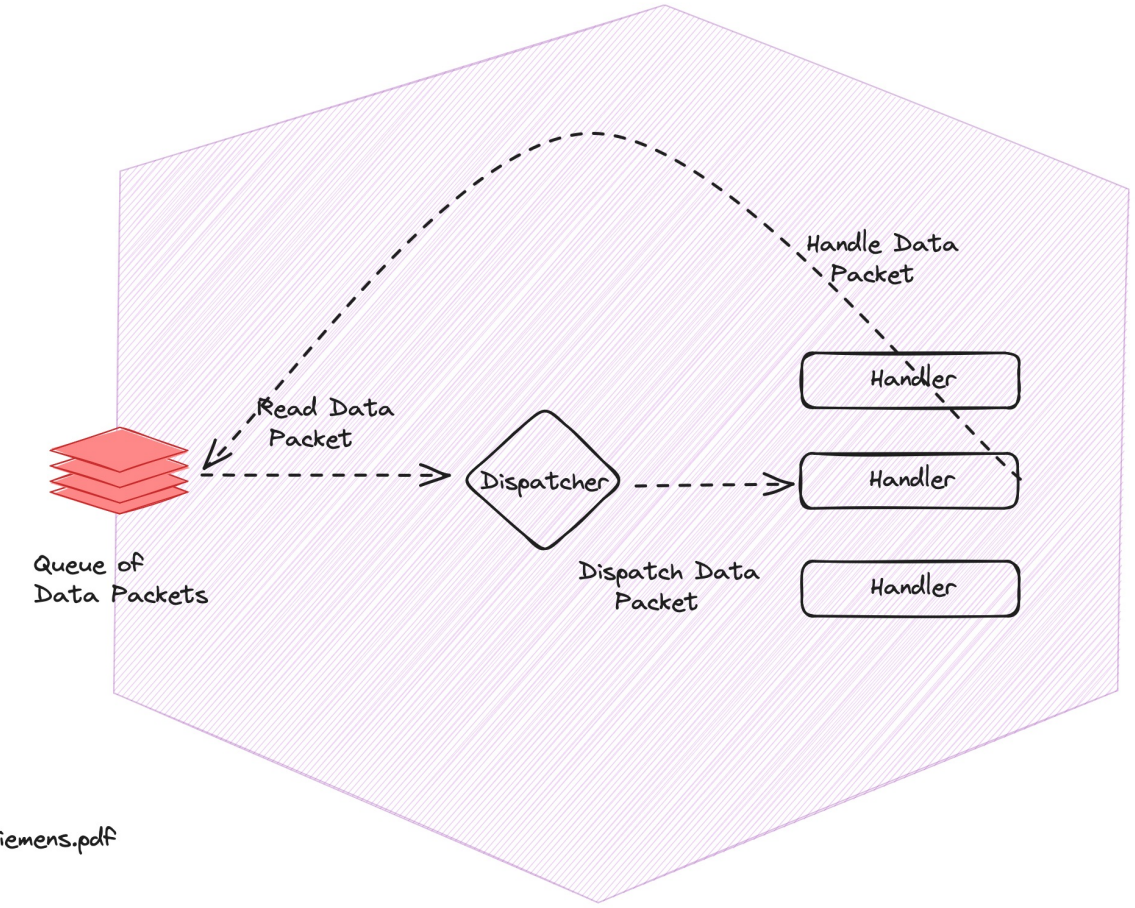
We partition state amongst actors, and each actor receives messages for its state.

Agenda

T: 20

- Objects
  - SOA
- Reactive
  - Reactive Programming
    - Dataflow
    - Flow Based Programming
    - Actors
    - Reactor Pattern
  - Reactive Systems
    - Message Passing
    - Resilience
    - Elasticity
    - Responsiveness





Reactor Pattern

Douglas Schmidt
http://www.dre.vanderbilt.edu/~schmidt/PDF/reactor-siemens.pdf

Single Threaded

The Reactor uses a single thread to: read from the queue; dispatch to a handler; and execute the handler.

Note that this preserves ordering and does not require locking to protect mutable state.

Agenda

T: 30

- Objects
  - SOA
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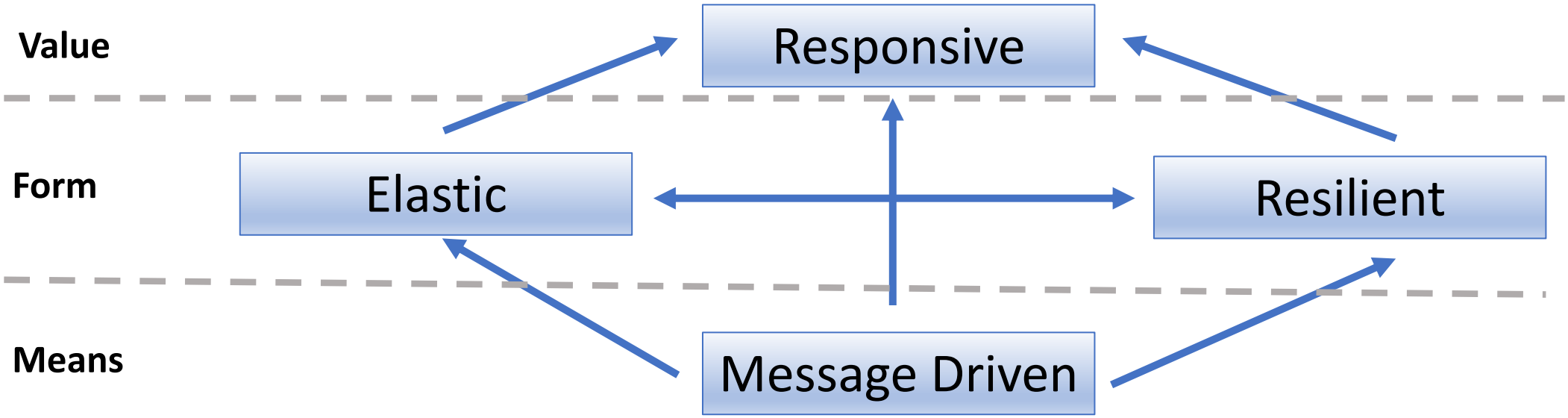
    - Actors
    - Flow Based Programming
    - Reactor Pattern
  - Reactive Systems
    - Message Passing
    - Resilience
    - Elasticity
    - Responsiveness


Value
Responsive
Form
Elastic
Resilient
Means
Message Driven

Agenda

T: 35

- Objects
  - SOA
- Reactive
  - Reactive Programming
    - Dataflow
    - Actors
    - Flow Based Programming
    - Reactor Pattern
  - Reactive Systems
    - Message Passing
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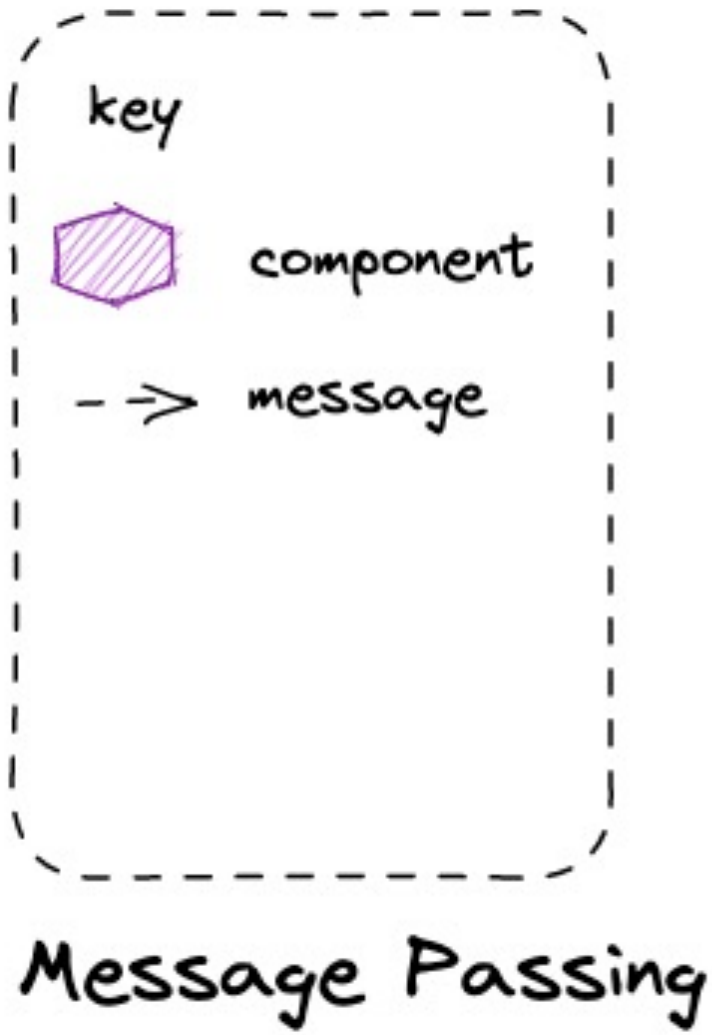
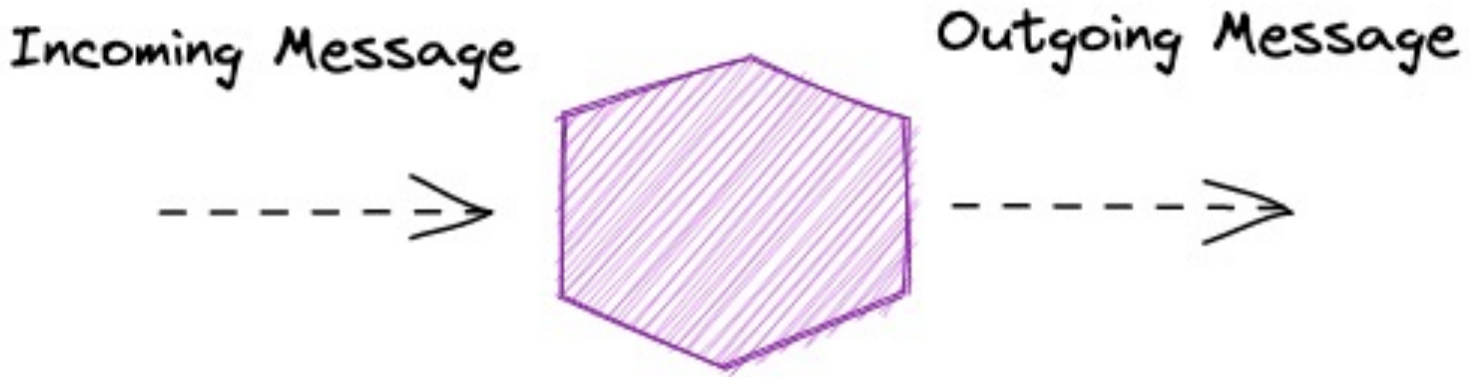
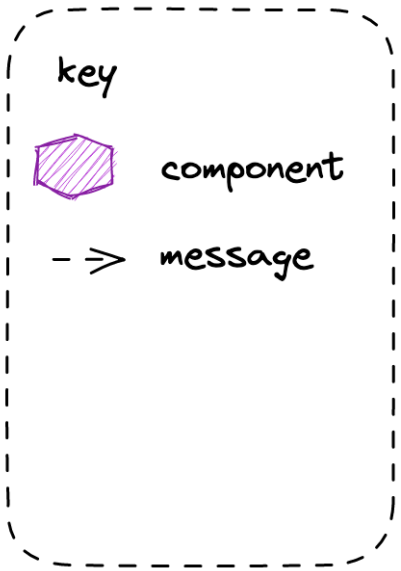
    - Elasticity
    - Responsiveness



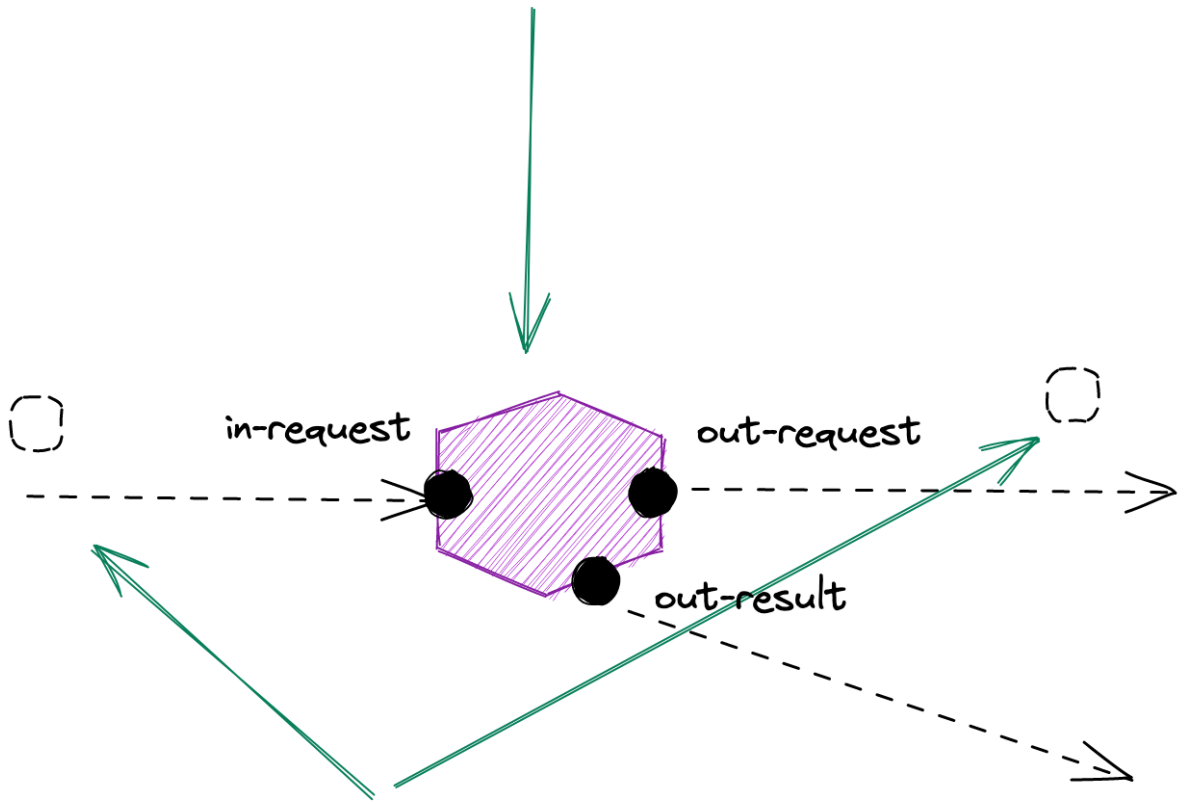


Message Passing is an asynchronous method of communication – both parties do not have to be simultaneously present for communication to occur, instead mail is delivered to 'mailbox' of some form for later retrieval.

Service should focus on a transformation to the data
Usually a verb + noun combination
Place Order or Onboard Restaurant



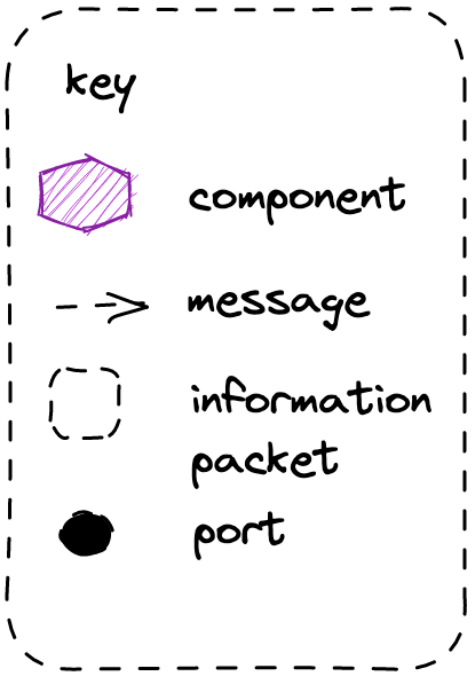
Message Passing

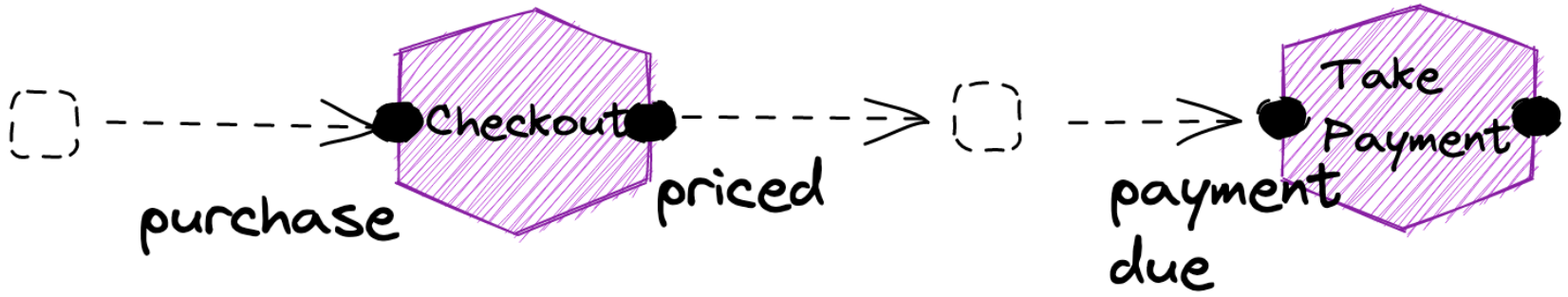


Things I am being told, a command

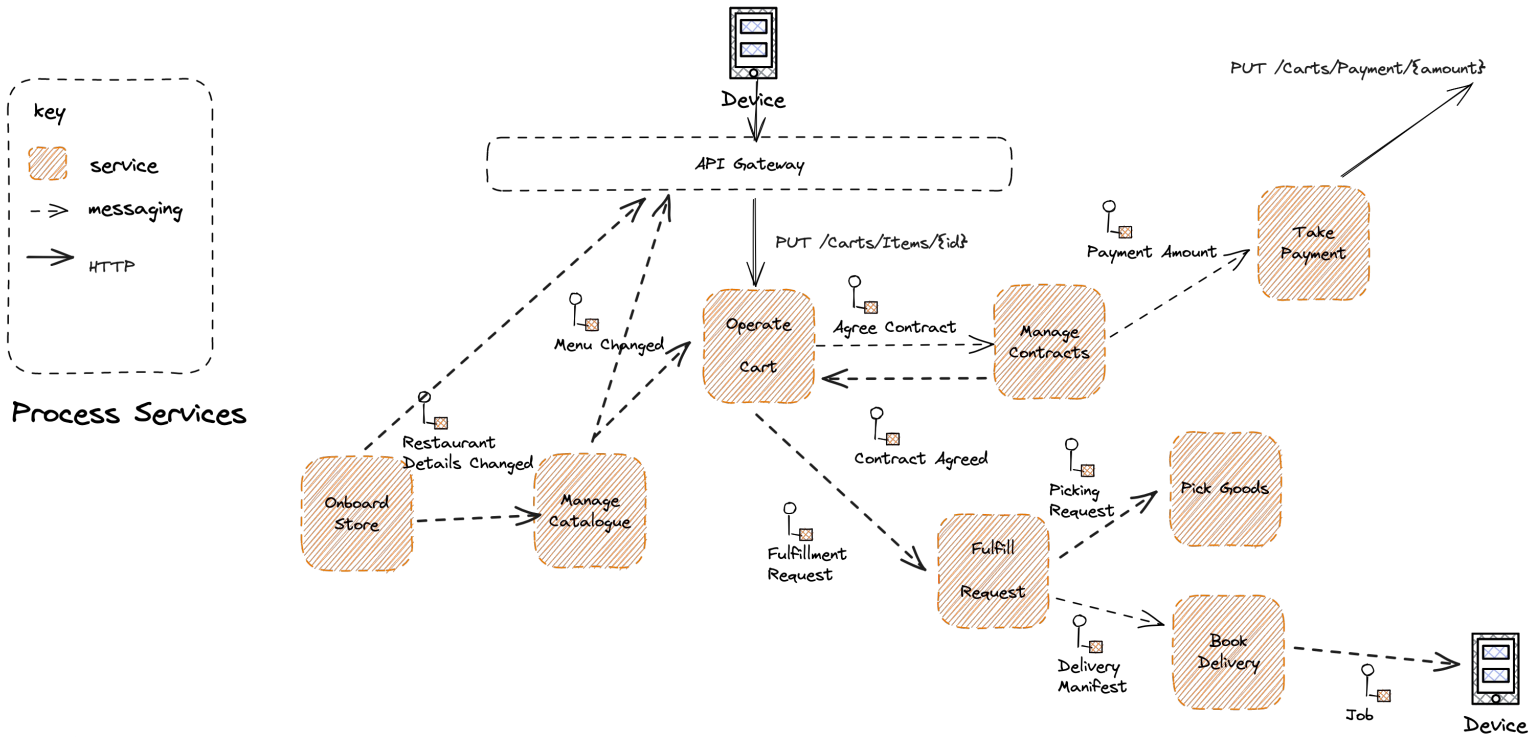
Things I know, facts, an event

Coordinate Dataflow A reactive *principle* where we “orchestrate a continuous steady flow of information” focusing on division by behavior, not structure





Partitioning Partition to take advantage of parallelism in the system, tasks that could be done concurrently with each other



Focus on Behavior not Data

I recommend thinking in terms of the service's responsibilities. (And don't say it's responsible for knowing some data!)
Does it apply policy? Does it aggregate a stream of concepts into a summary?
Does it facilitate some kinds of changes? Does it calculate something? And so on.
Notice how moving through the business process causes previous information to become effectively read-only?

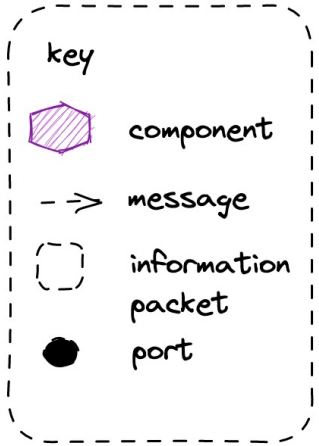
- Michael Nygard

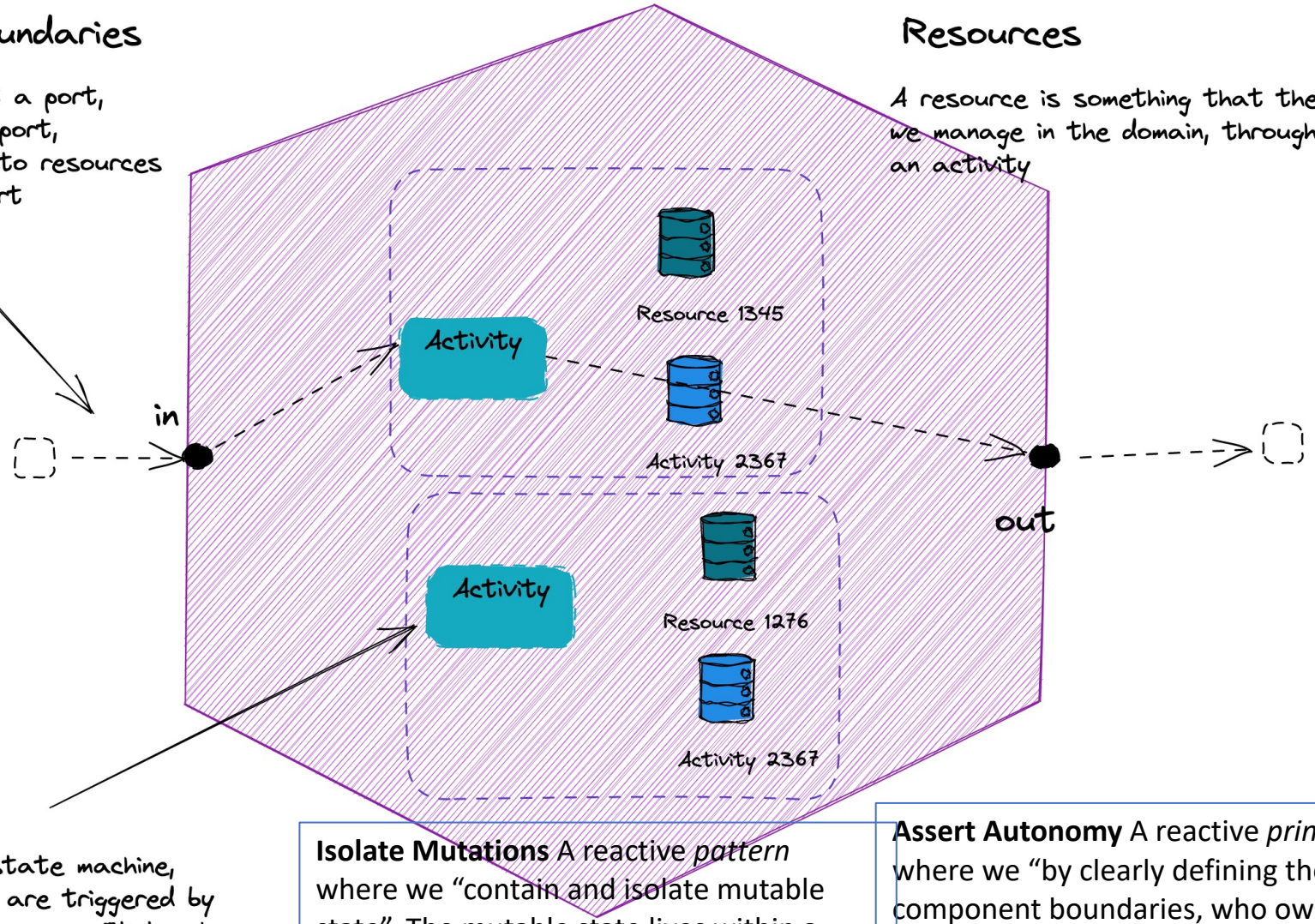
Explicit Boundaries

Work arrives at a port,
or leaves by a port,
and all access to resources
is only via a port

Resources

A resource is something that the
we manage in the domain, through
an activity





Autonomous Component

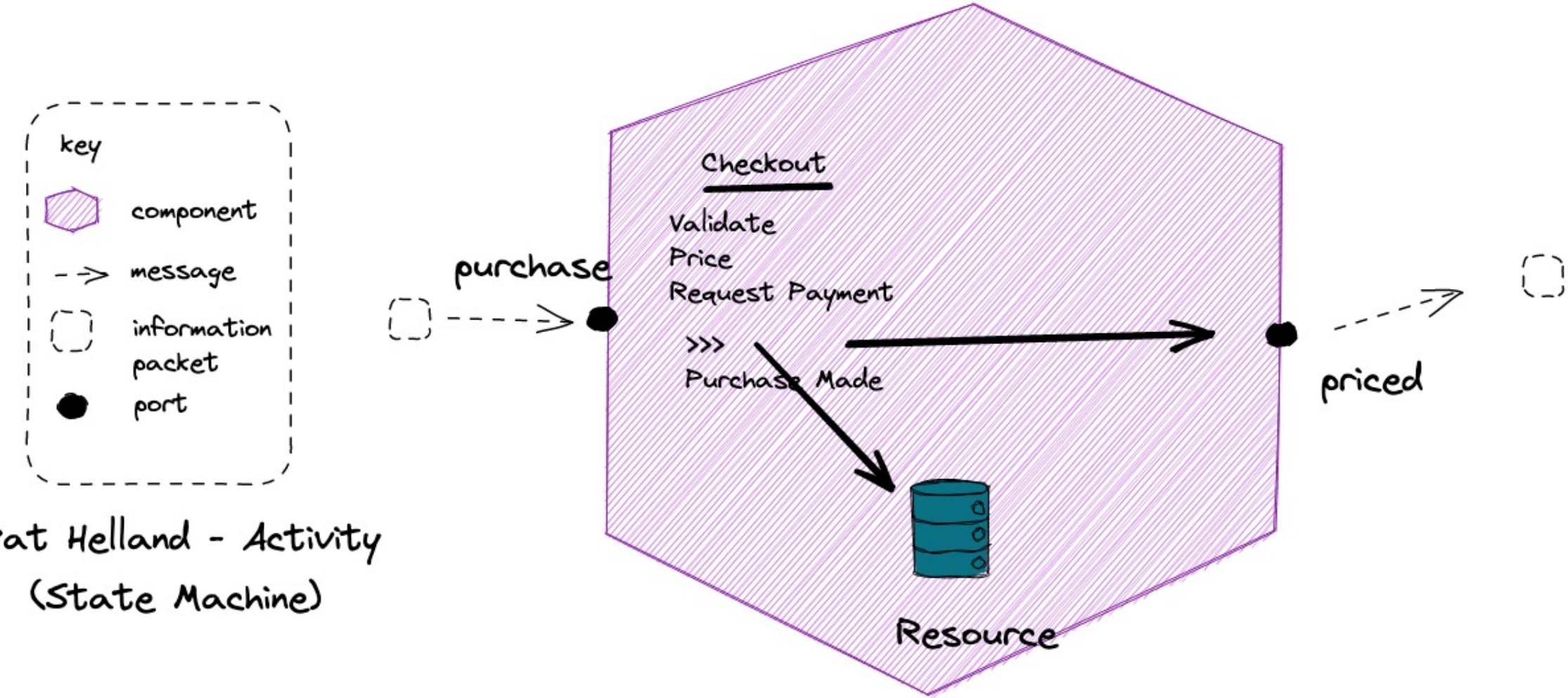
Pat Helland

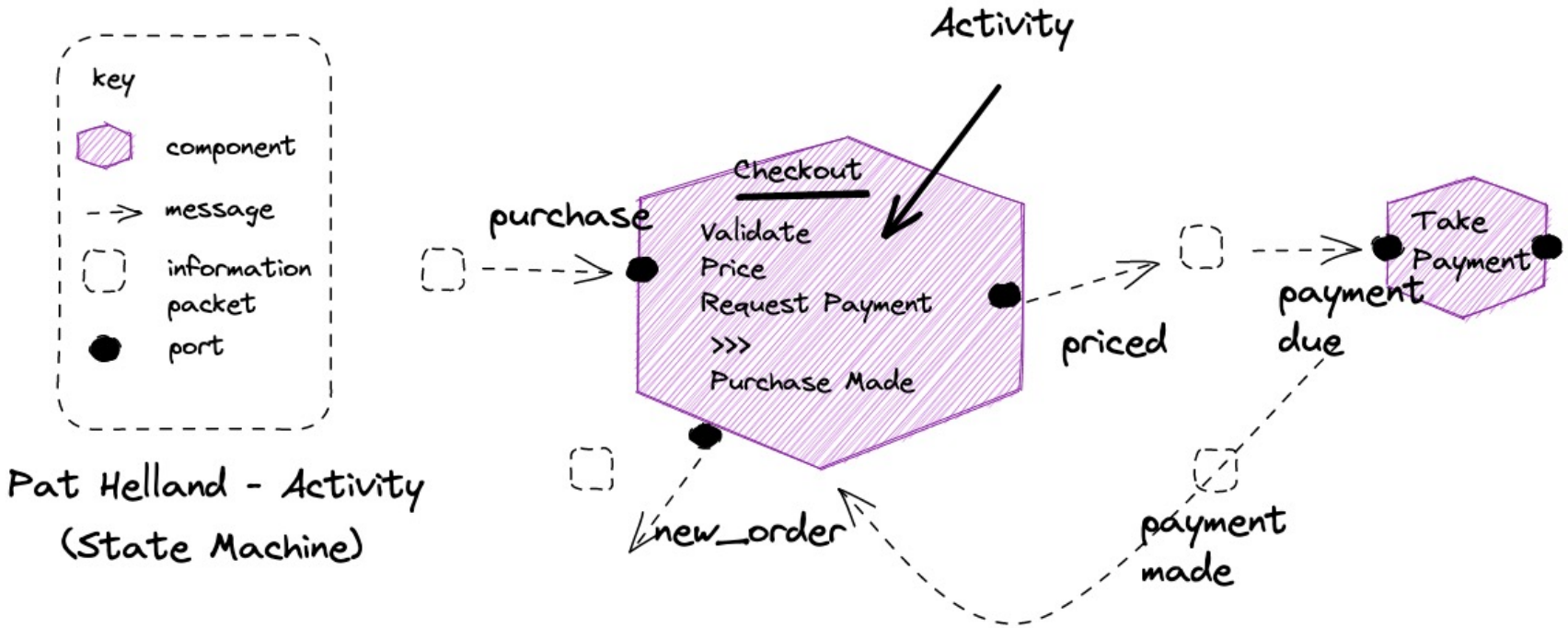
Activities

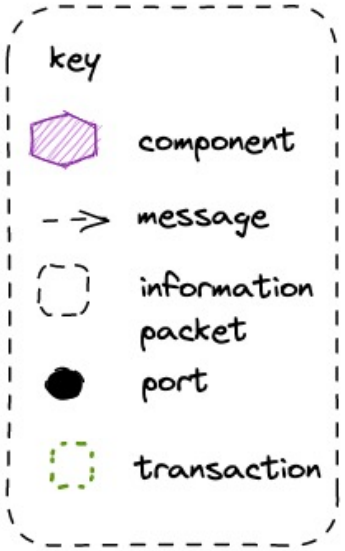
An activity is a state machine,
whose transitions are triggered by
the arrival of messages. It tracks
messages in and out, current state.

Isolate Mutations A reactive *pattern* where we "contain and isolate mutable state". The mutable state lives within a component that has a defined boundary.

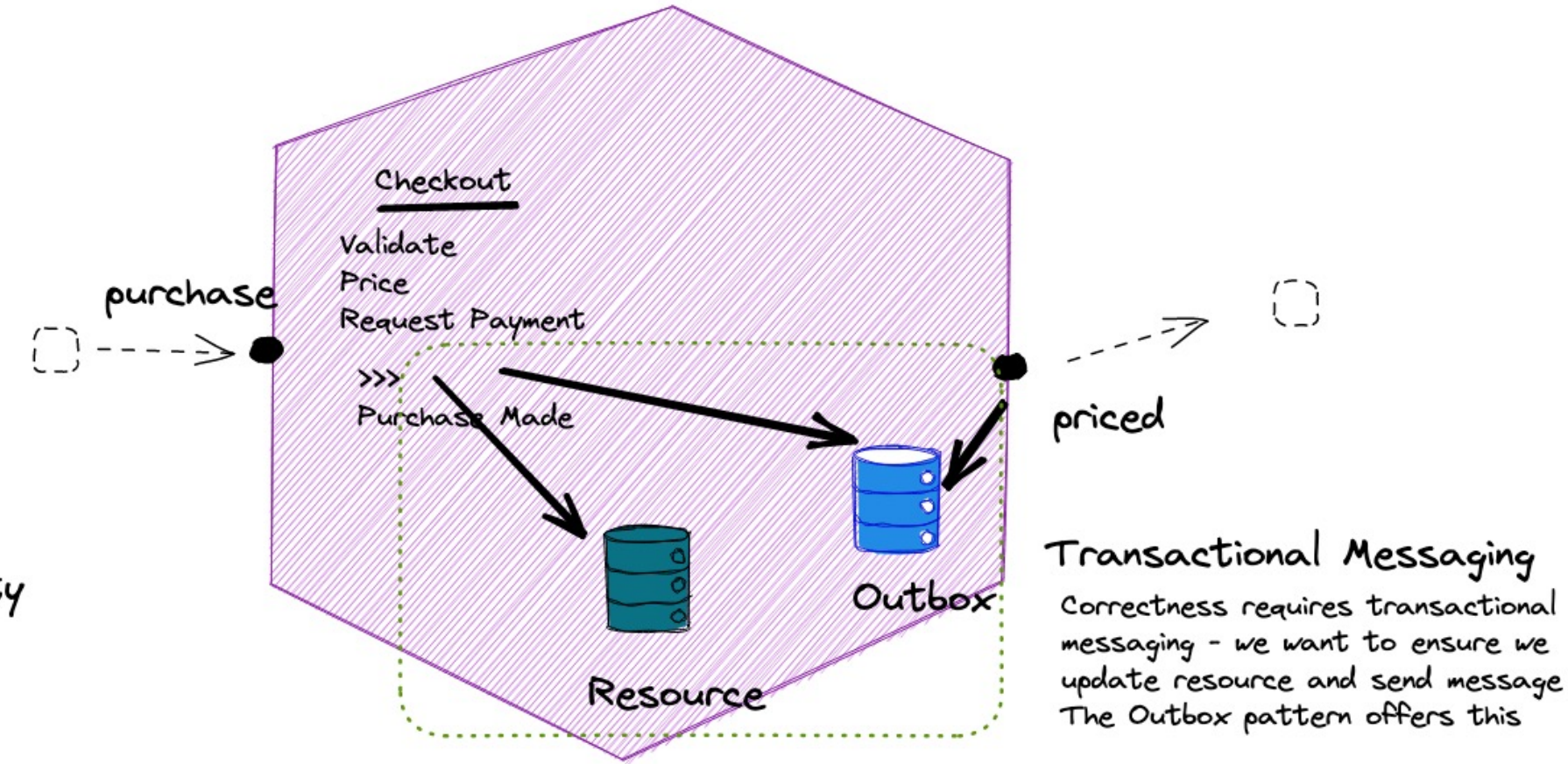
Assert Autonomy A reactive *principle* where we "by clearly defining the component boundaries, who owns what data and how the owners make it available"


key
component
message
information packet
port
Pat Helland - Activity (State Machine)
purchase
Checkout
Validate
Price
Request Payment
>>>
Purchase Made
priced
Resource


key
component
message
information packet
port
Pat Helland - Activity (State Machine)
Activity
Checkout
purchase
Validate
Price
Request Payment
>>>
Purchase Made
priced
payment due
Take Payment
new_order
payment made

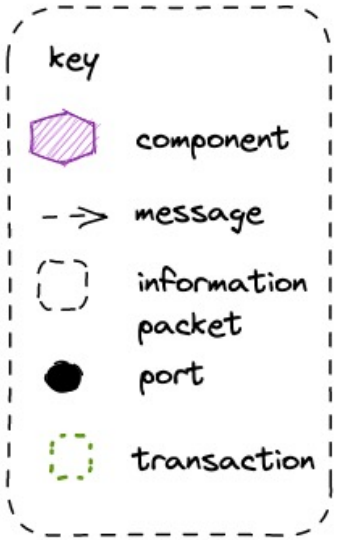


Pat Helland - Activity (State Machine)

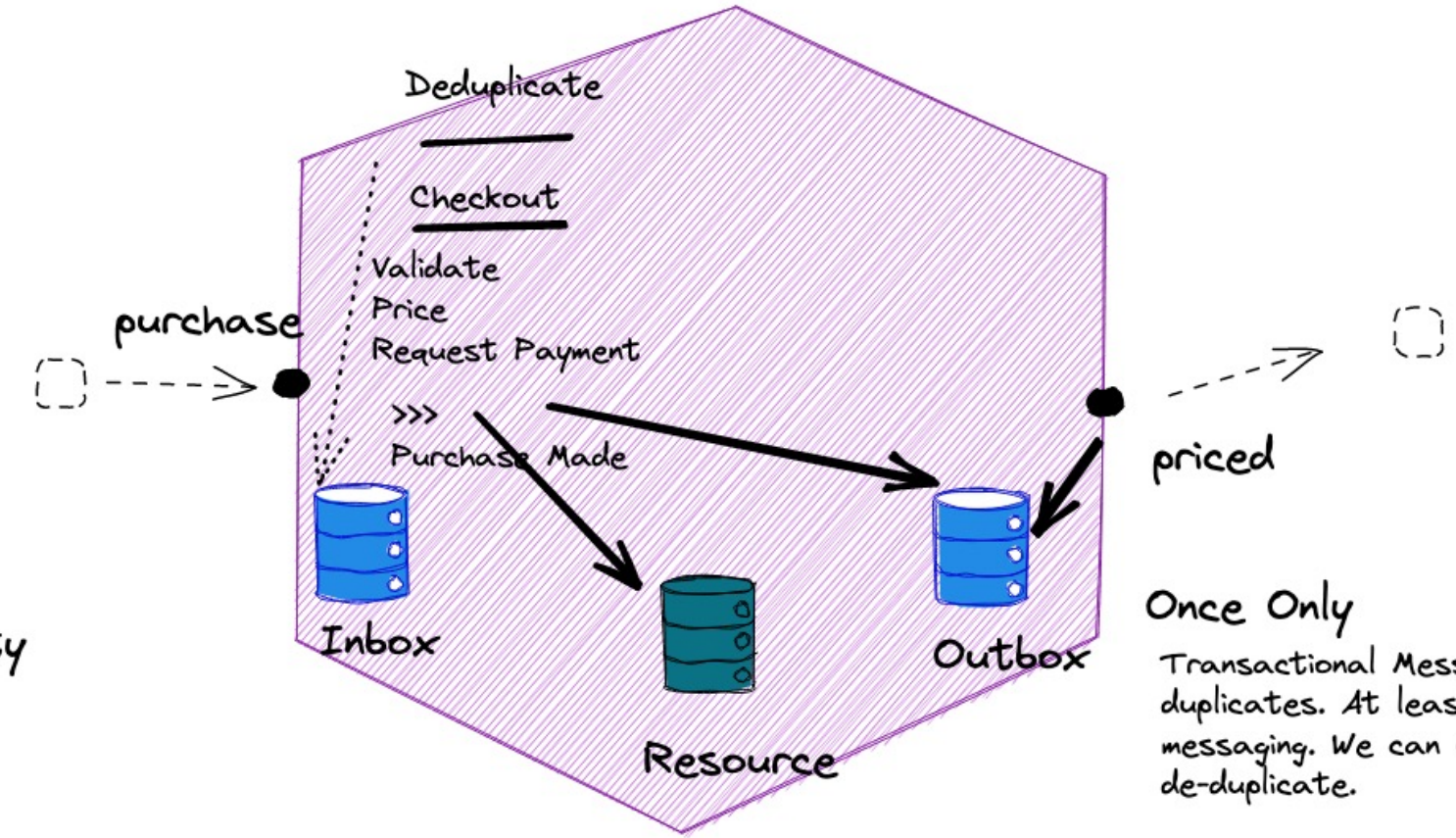


Transactional Messaging

Correctness requires transactional messaging - we want to ensure we update resource and send message
The Outbox pattern offers this

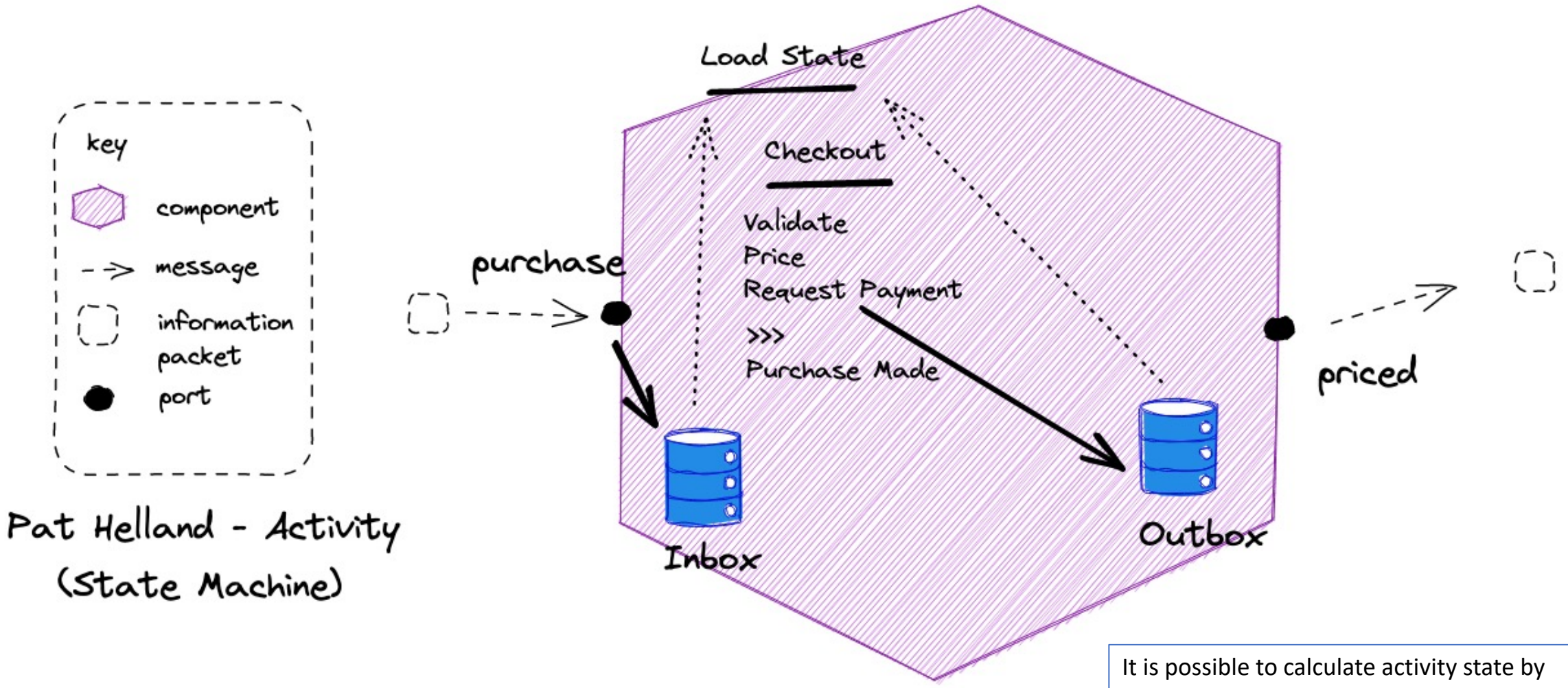


Pat Helland - Activity (State Machine)

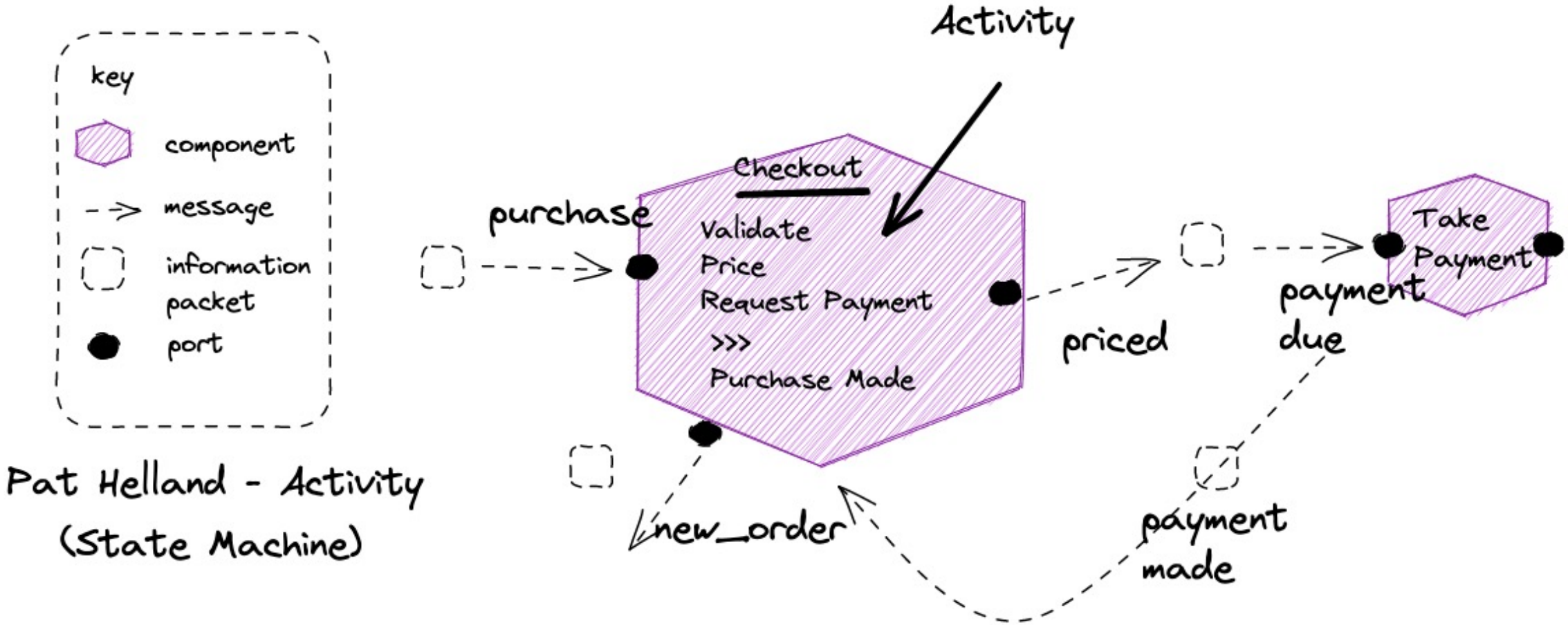


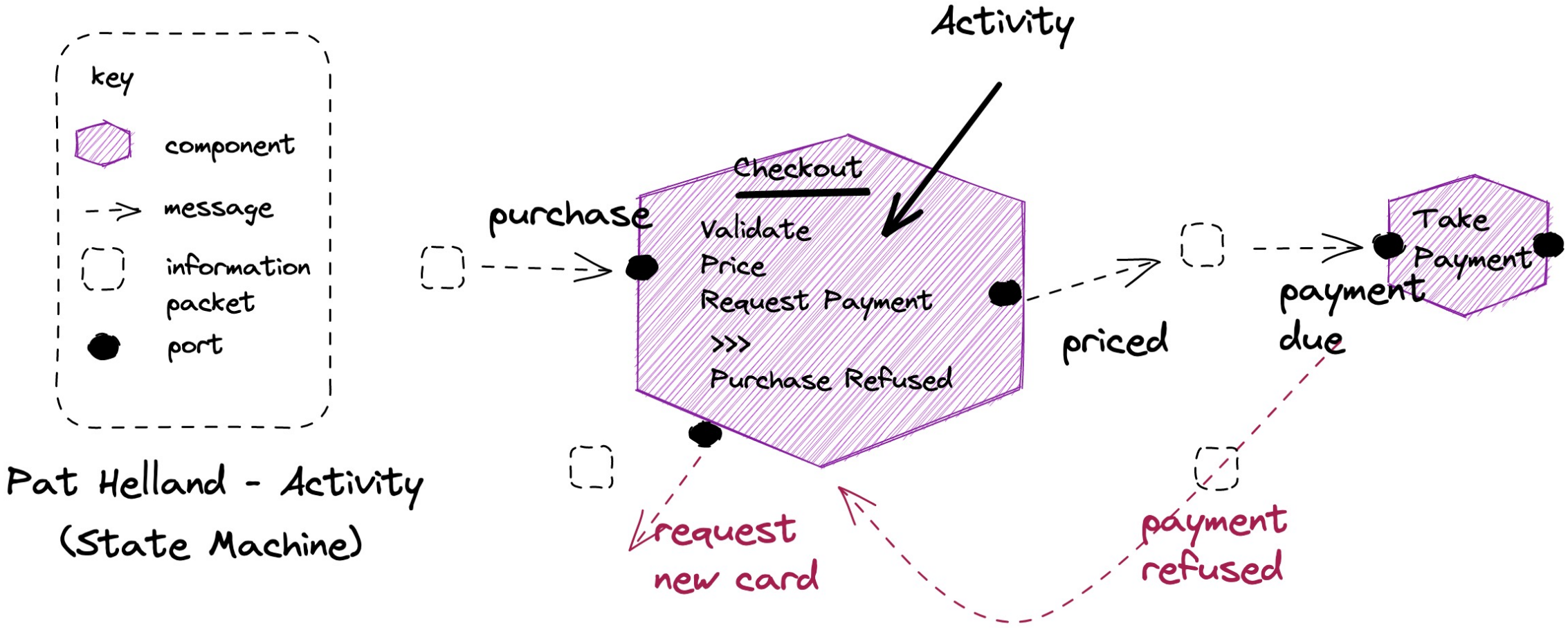
Once Only

Transactional Messaging will send us duplicates. At least once, guaranteed messaging. We can use an Inbox to de-duplicate.



It is possible to calculate activity state by comparing the inbox and outbox to determine where a flow reached, in the event of failure, over storing current state.


key
component
message
information packet
port
Activity
Checkout
purchase
Validate
Price
Request Payment
>>>
Purchase Made
priced
Take Payment
payment due
new_order
payment made
Pat Helland - Activity (State Machine)


key
component
message
information packet
port
Activity
Checkout
purchase
Validate
Price
Request Payment
>>>
Purchase Refused
priced
Take Payment
payment due
request new card
payment refused
Pat Helland - Activity (State Machine)

Agenda

T: 45

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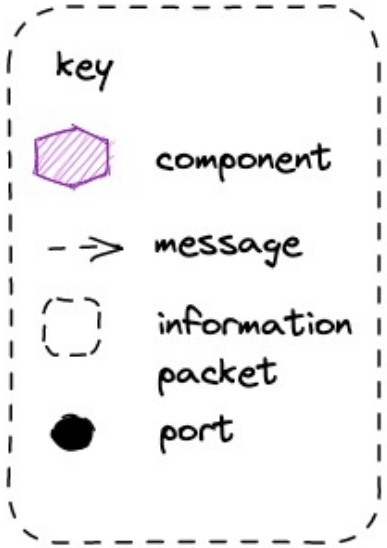
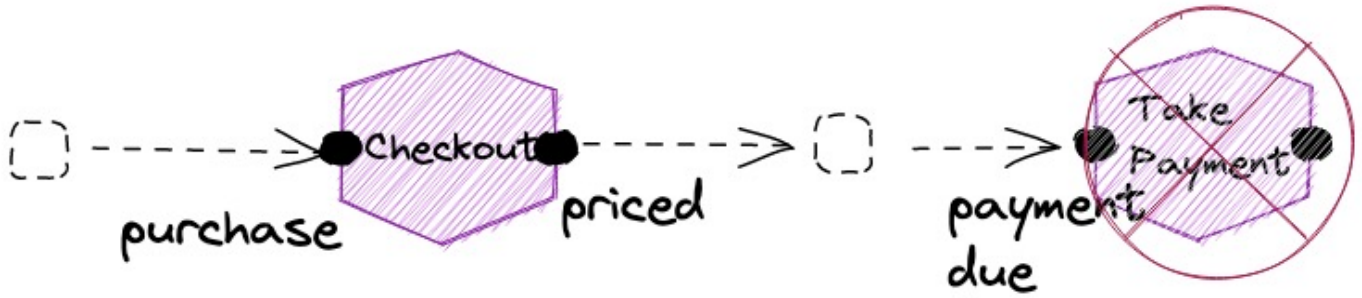
    - Responsiveness

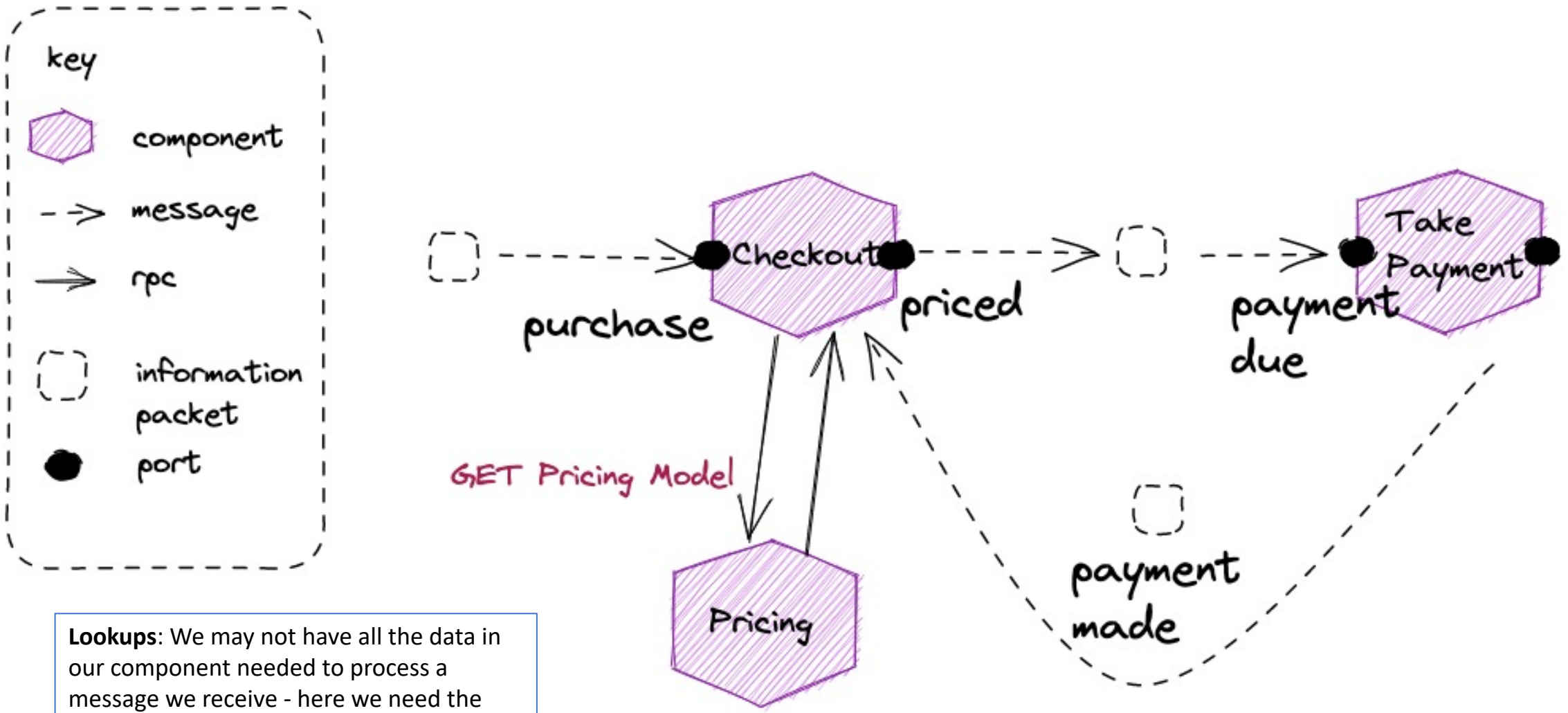




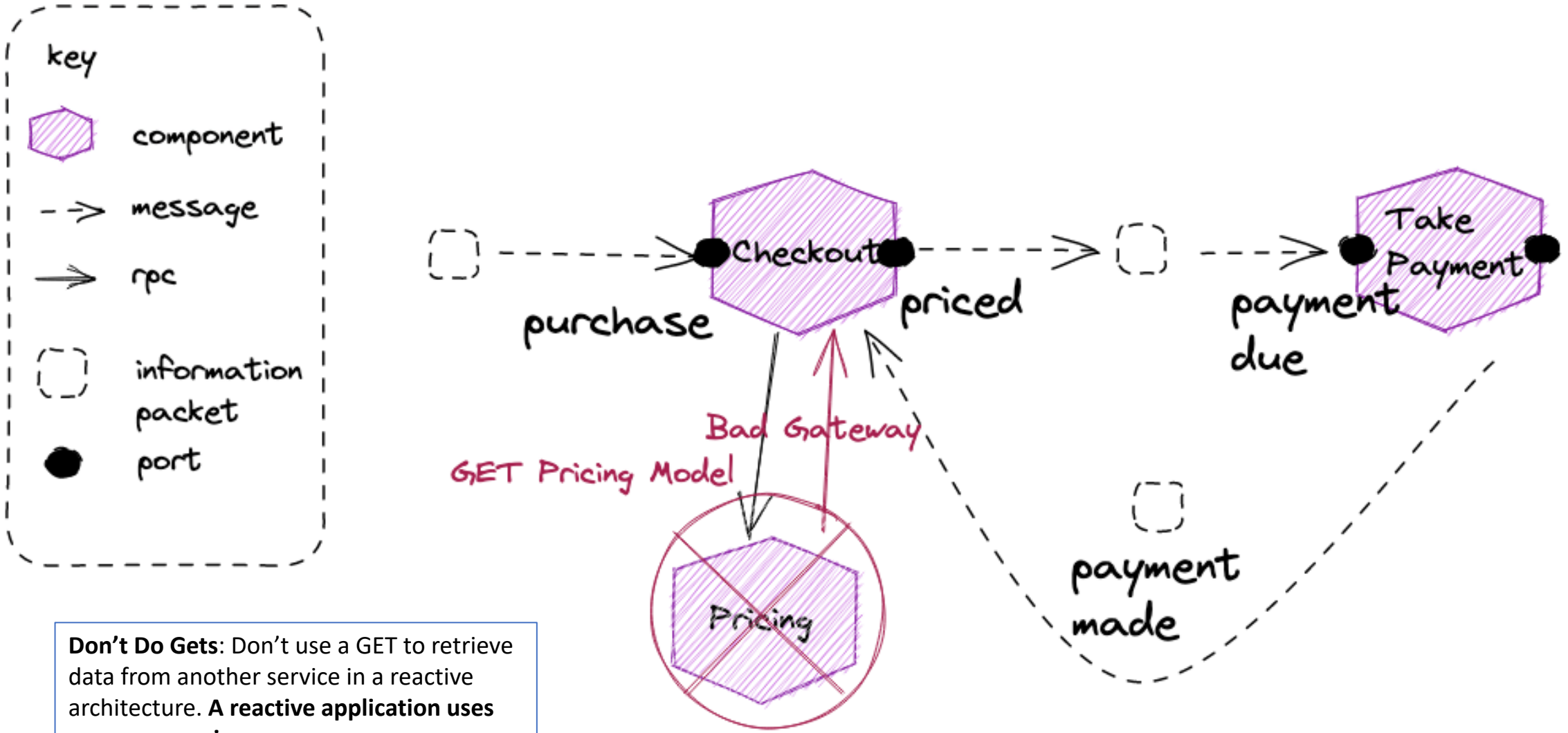
Bulkheads: In an asynchronous conversation a fault does not propagate back up the chain – we have a bulkhead that protects us against failure

Work Queues on a Fault

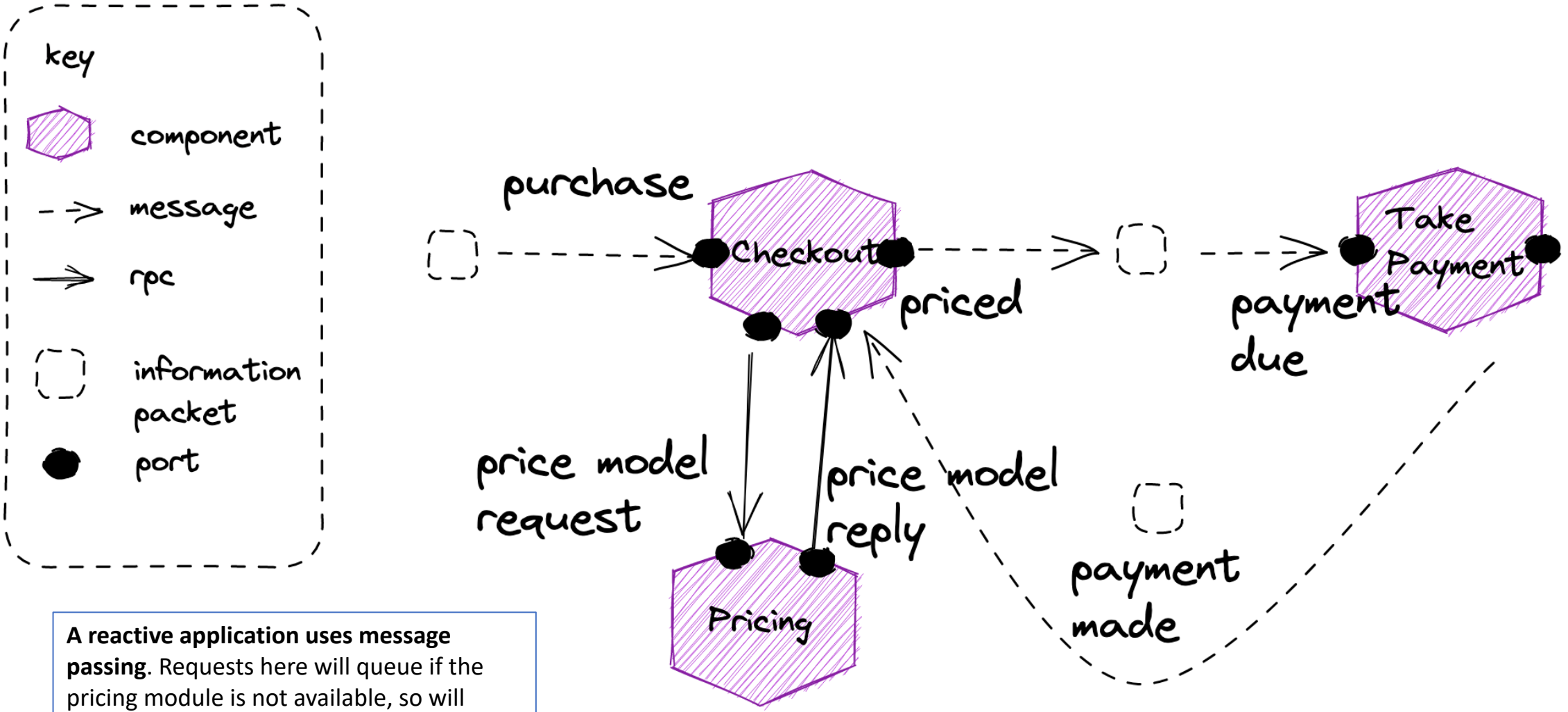
If Take Payment is not available, we can queue requests. When it starts up, Take Payment can process those requests and respond as normal.



Lookups: We may not have all the data in our component needed to process a message we receive - here we need the prices for your purchase – which implies a lookup such as an HTTP GET to the owner

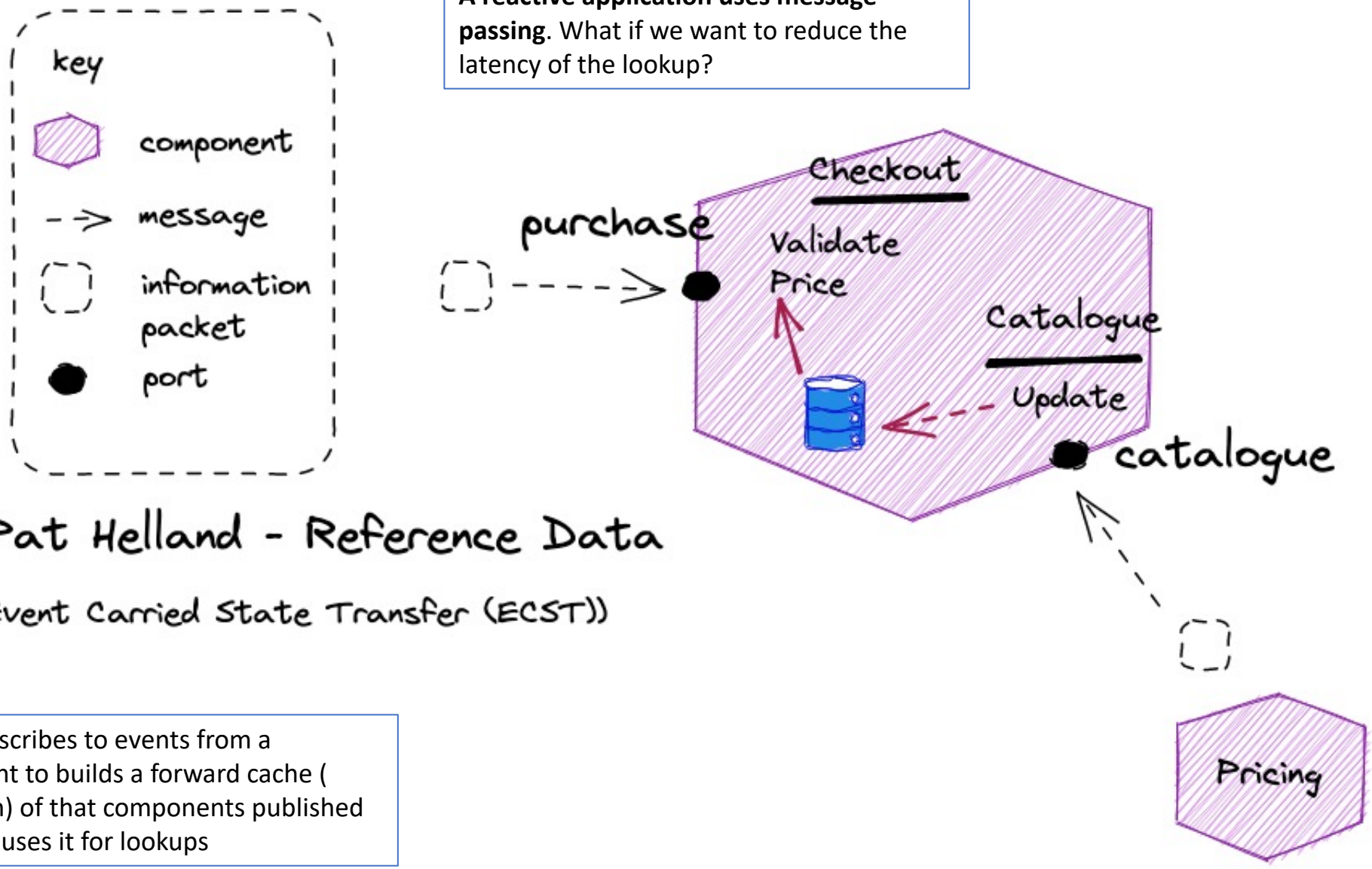


Don't Do Gets: Don't use a GET to retrieve data from another service in a reactive architecture. **A reactive application uses message passing**.



A reactive application uses message passing. Requests here will queue if the pricing module is not available, so will eventually be serviced.

A reactive application uses message passing. What if we want to reduce the latency of the lookup?

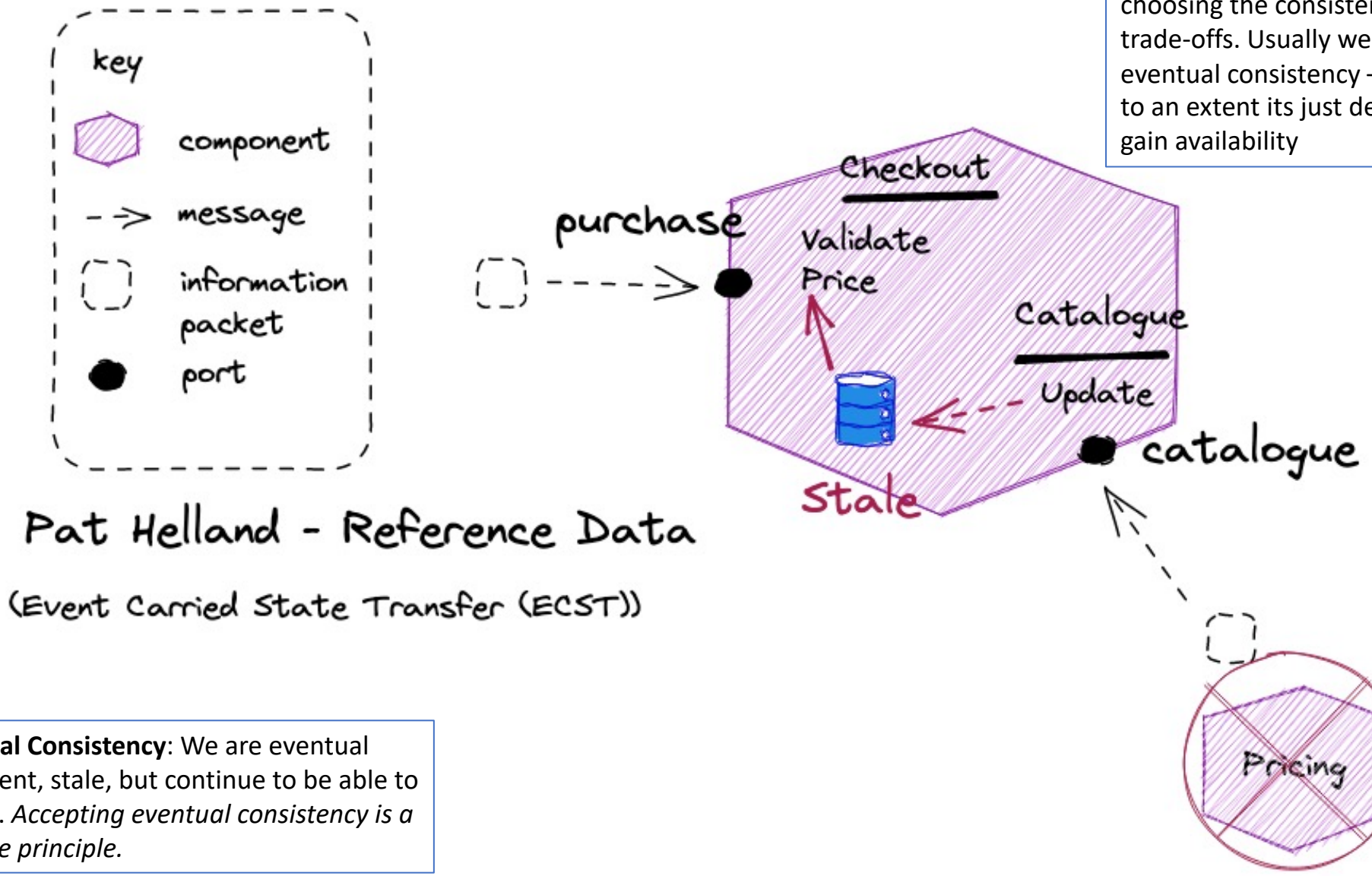


Pat Helland - Reference Data

(Event Carried State Transfer (ECST))

ECST: Subscribes to events from a component to builds a forward cache (projection) of that components published data, and uses it for lookups

Tailor Consistency: Reactive advises choosing the consistency you need for its trade-offs. Usually we can tolerate eventual consistency – nearly everything is to an extent its just degrees of latency – to gain availability



Pat Helland - Reference Data

(Event Carried State Transfer (ECST))

Eventual Consistency: We are eventual consistent, stale, but continue to be able to lookup. *Accepting eventual consistency is a reactive principle.*

Let it Crash Pattern

(Candea & Fox "Crash-Only Software)

Transient or rare failures are hard to detect

Recovery from a fault may be a complex problem

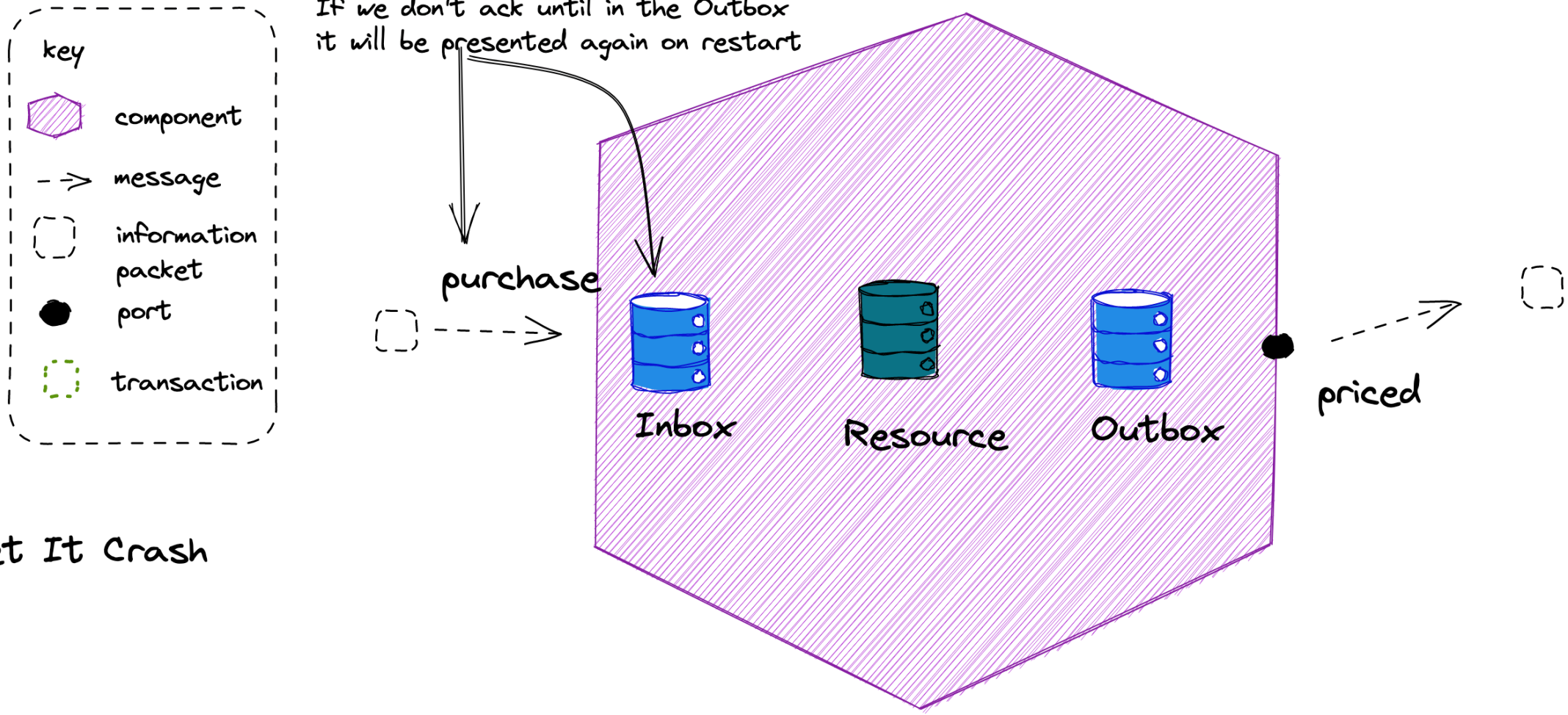
Crash and Restart =>

Start Up is Recovery

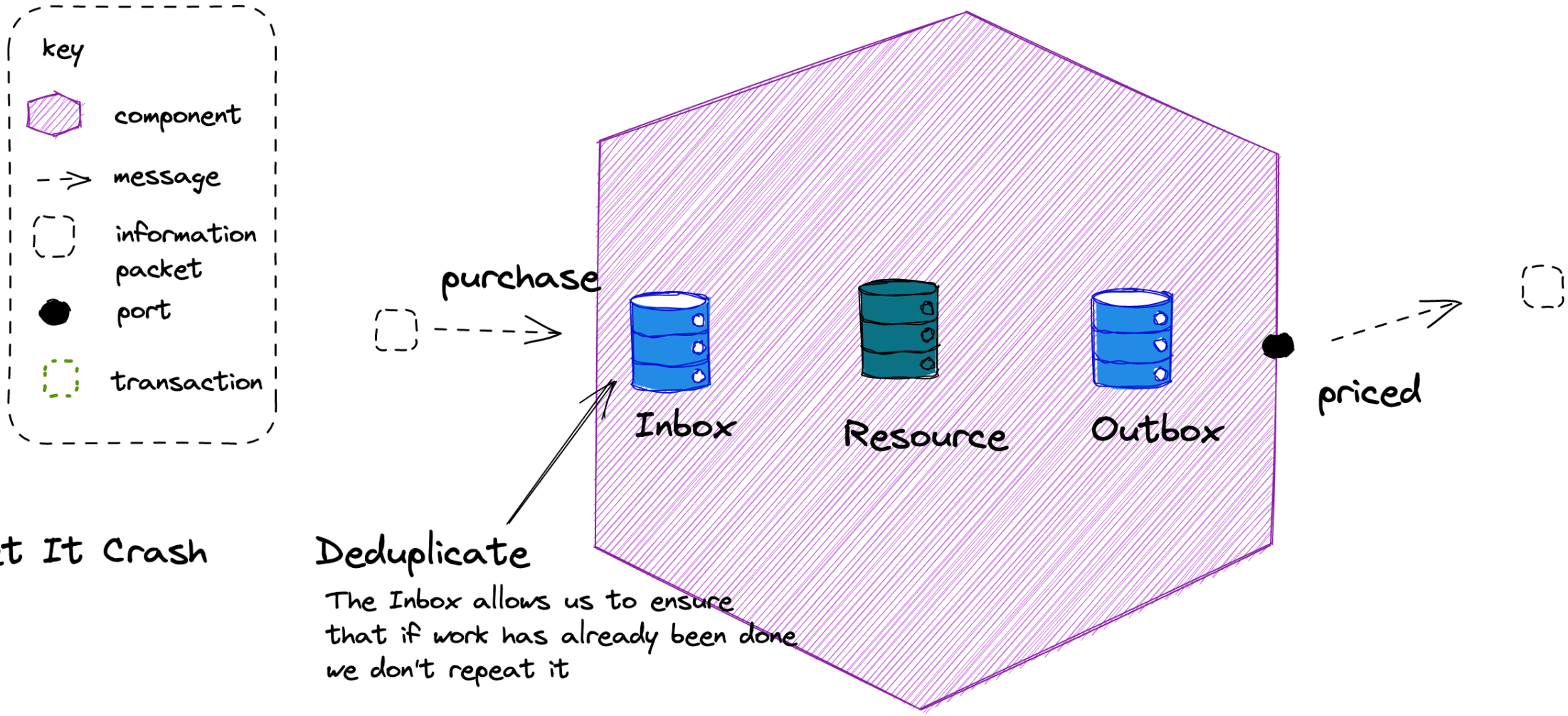
Shut Down is Clean

Don't Ack until Done

A message is a queue of work
If we don't ack until in the Outbox
it will be presented again on restart



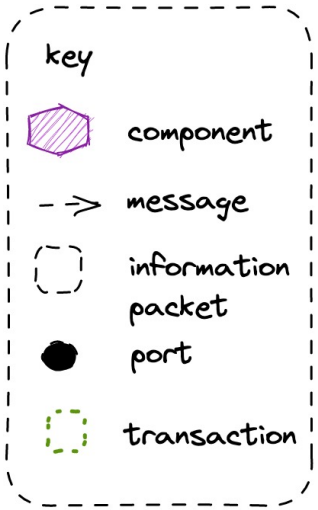
Let It Crash



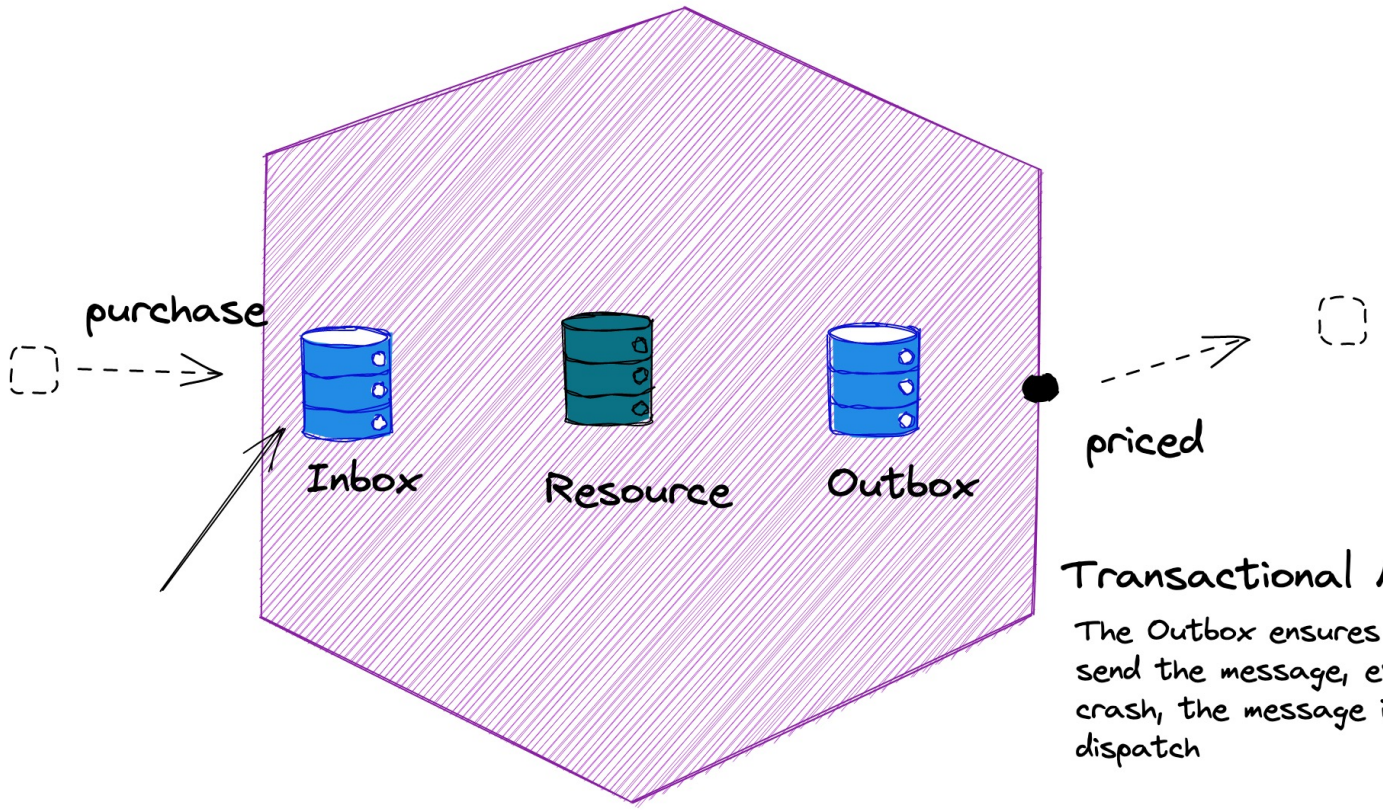
Let It Crash

Deduplicate

The Inbox allows us to ensure that if work has already been done we don't repeat it

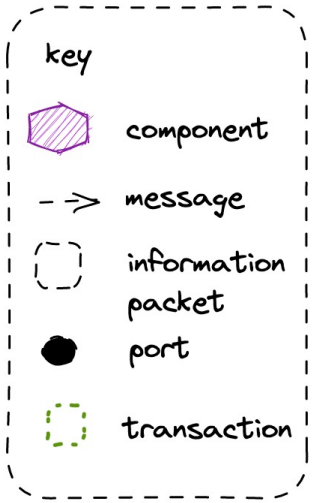


Let It Crash

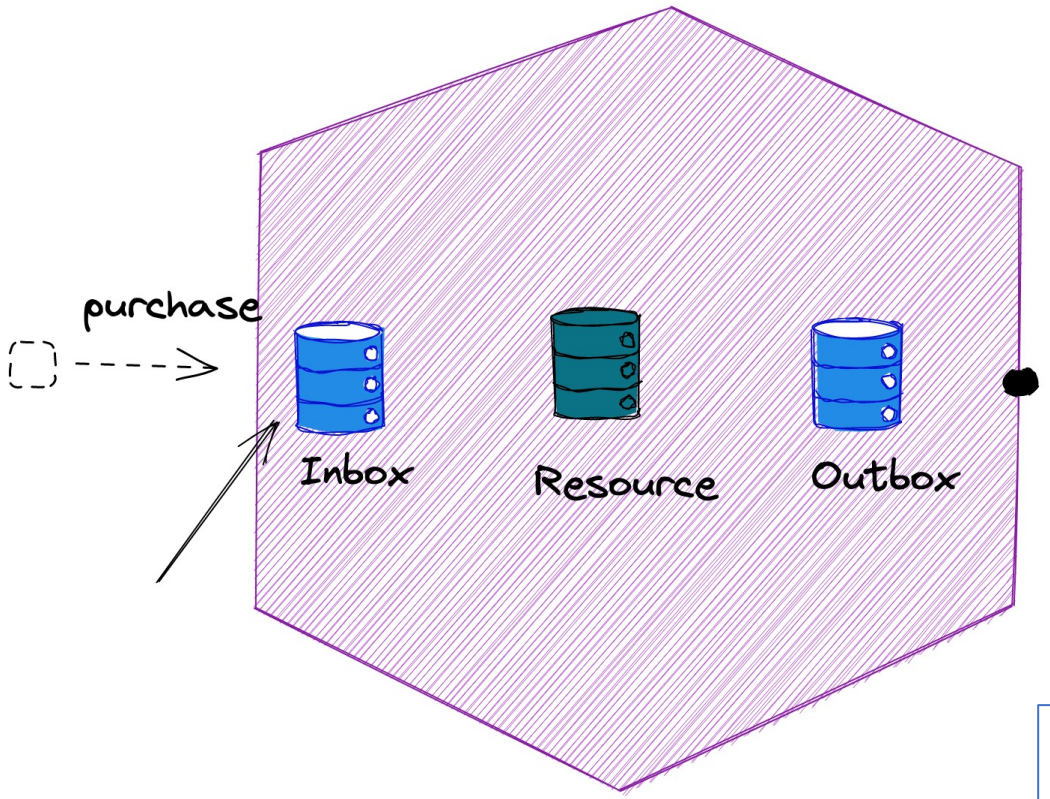


Transactional Messaging

The Outbox ensures that we will eventually send the message, even if our component should crash, the message is in the Outbox for later dispatch



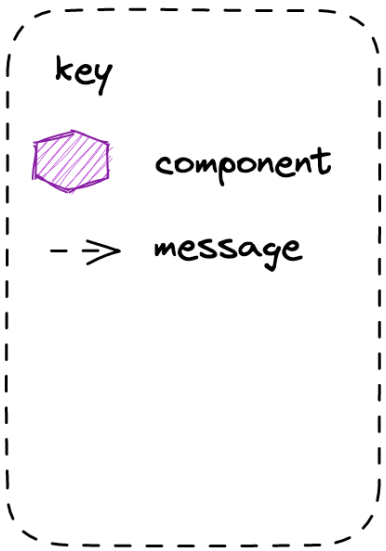
Let It Crash



Asynchronous Messaging

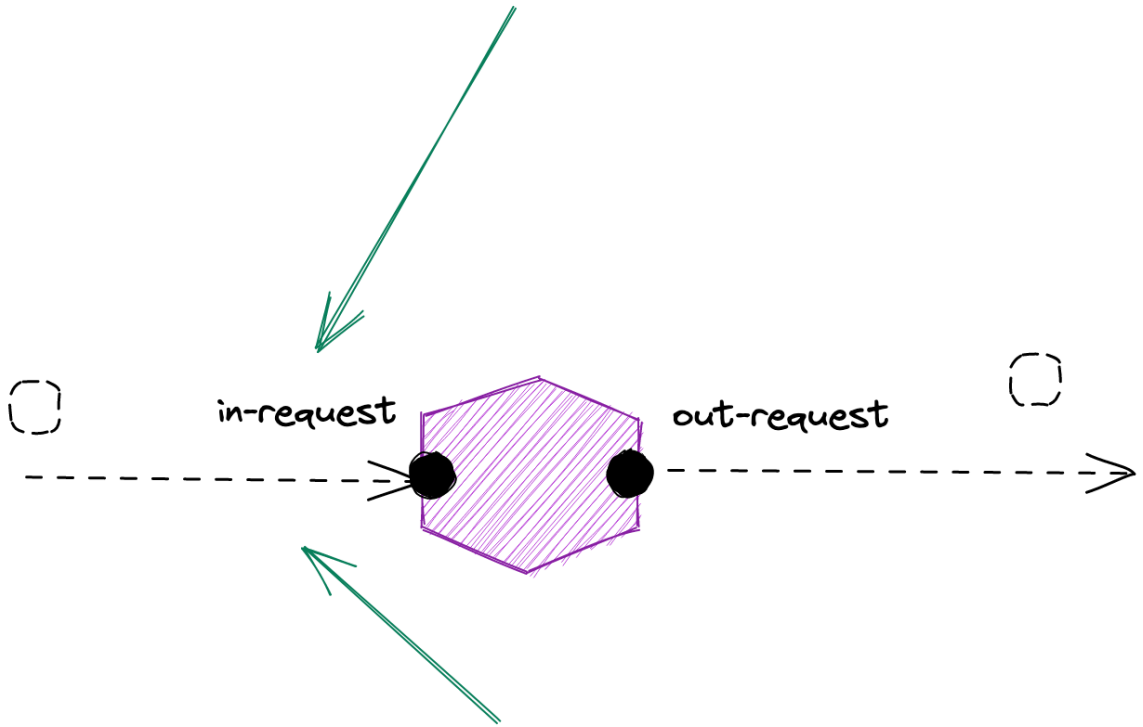
Because we communicate via messaging we are resilient to the use of "Let it Crash" by other components because we queue messages for their restart

ECST: Don't forget, because we use ECST and not a GET, we support "Let it Crash" by components where we need to lookup



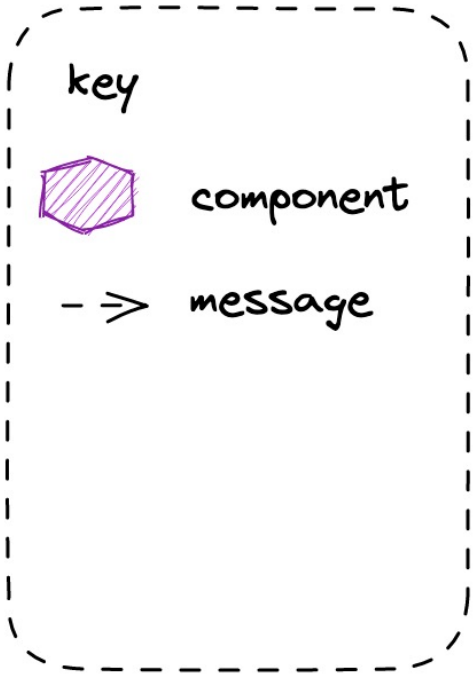
Message Passing

Push => open socket, middleware calls us as messages arrive
Pull => We poll for messages

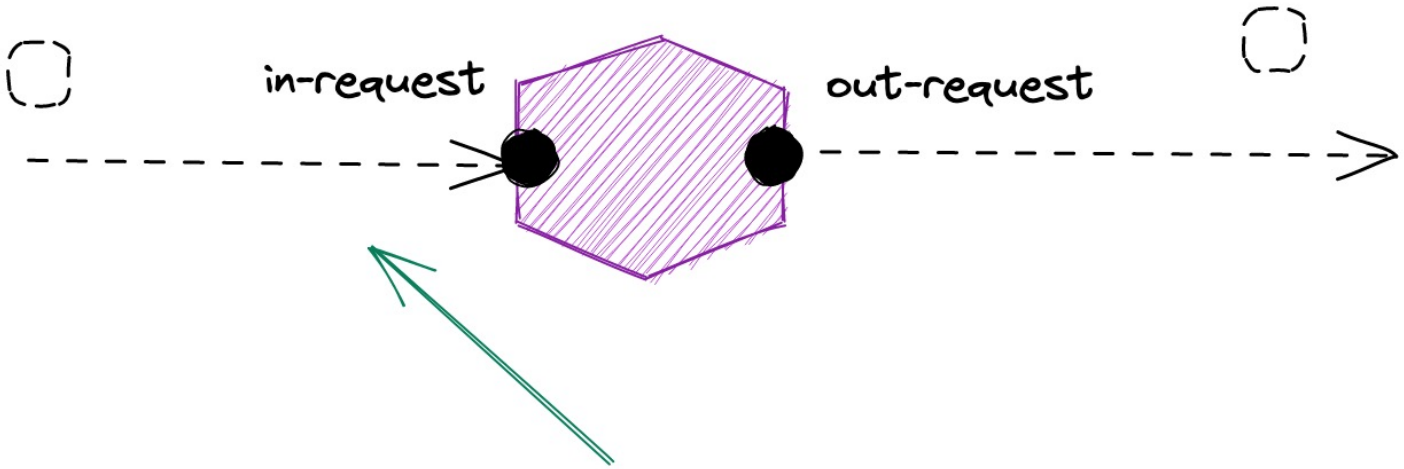


Backpressure

Push => Need to control how many messages are "in flight" with us
Pull => We control the rate at which we poll

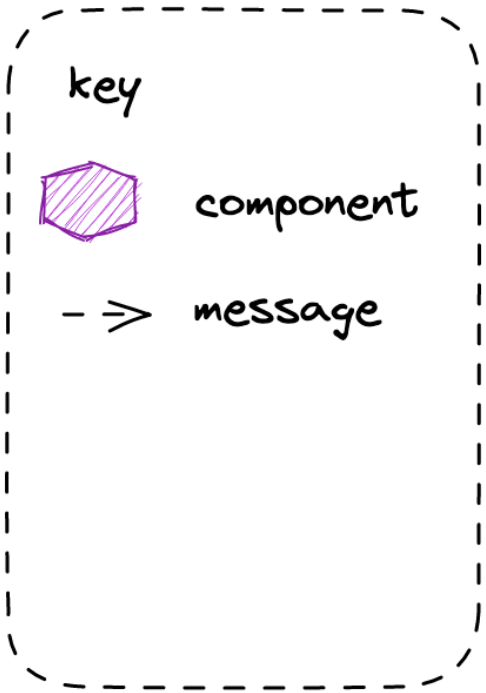


Message Passing

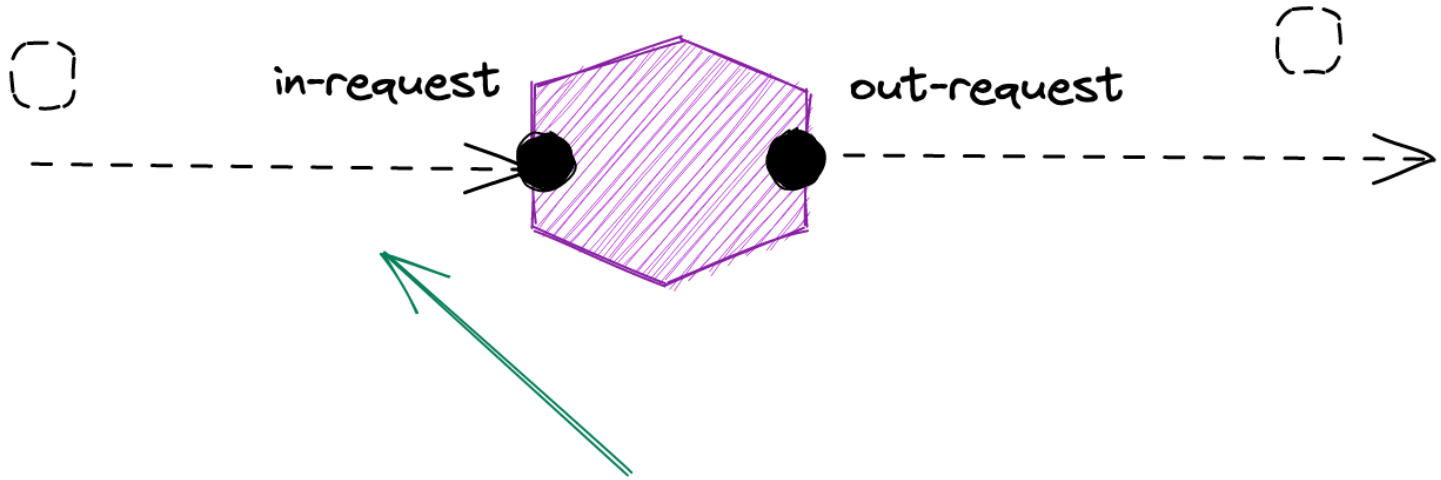


Circuit Breaker

We may want to stop consuming, due to a fault.
We can periodically let a message through to see if the fault has cleared.



Message Passing



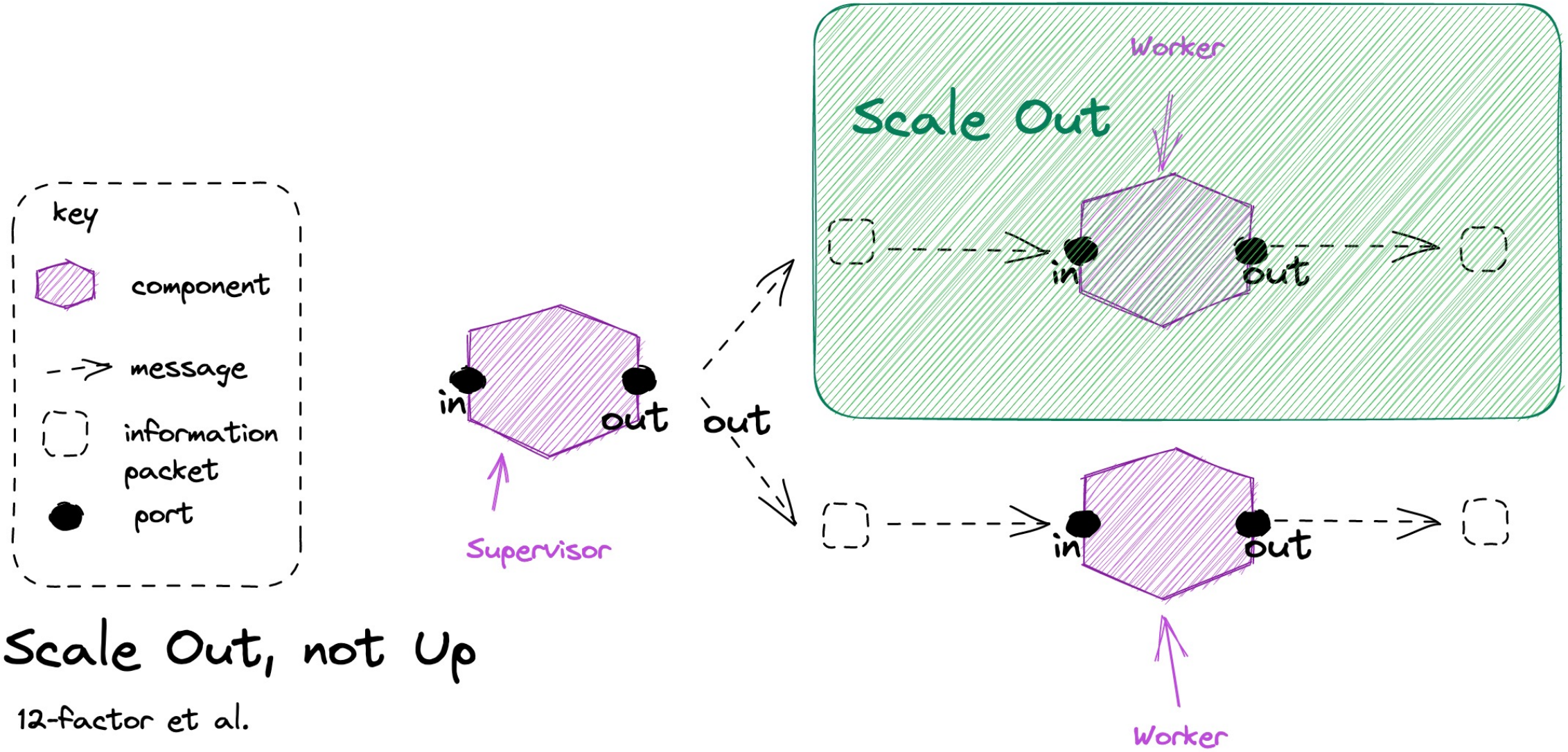
Load Shedding

Sometimes we may prefer to simply drop messages or shed load, when there is a fault.

Agenda

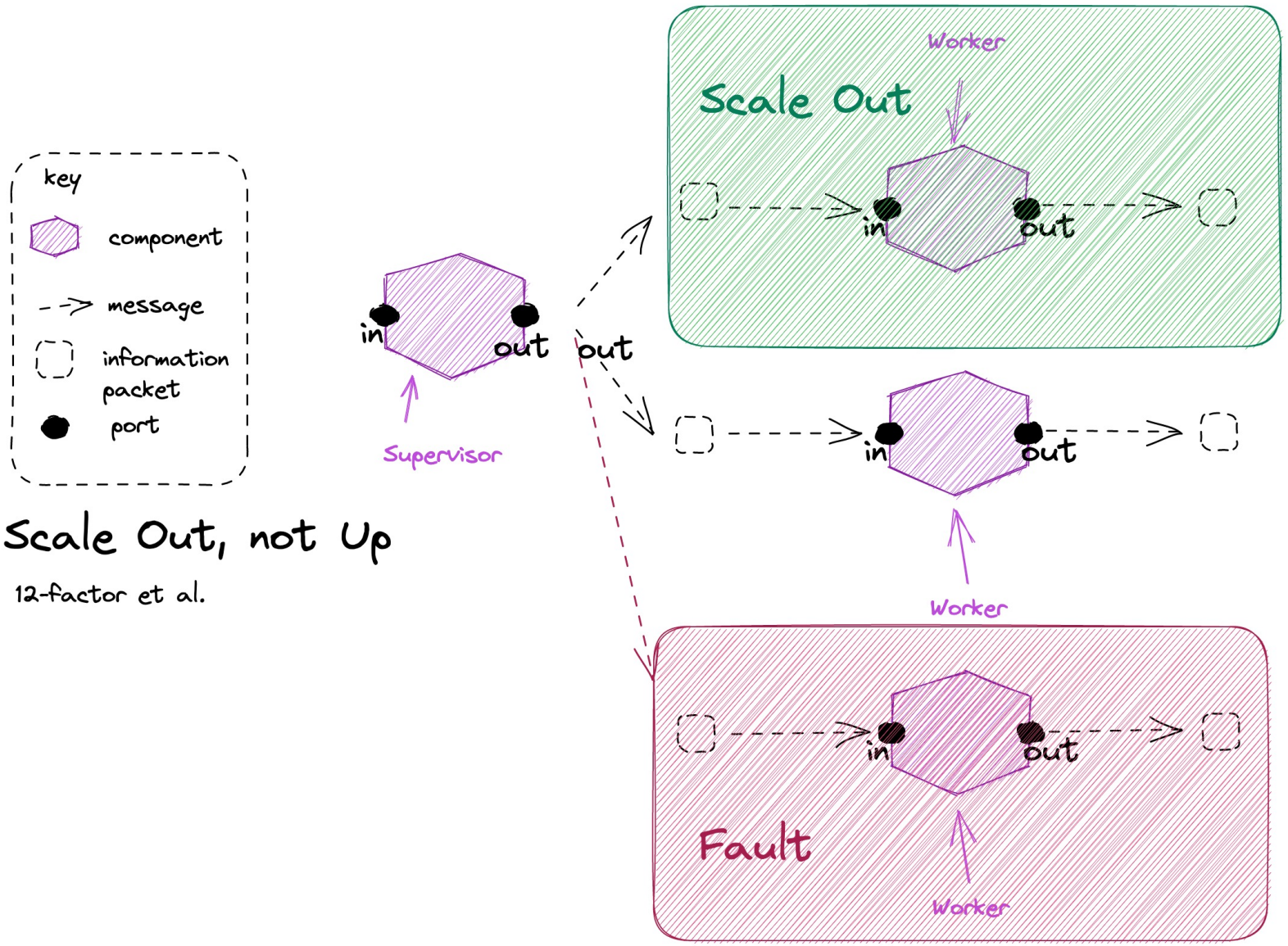
T: 50

- Objects
  - SOA
- Reactive
  - Reactive Programming
    - Dataflow
    - Actors
    - Flow Based Programming
    - Reactor Pattern
  - Reactive Systems
    - Message Passing
    - Resilience
    - Elasticity
    - Responsiveness



Scale Out, not Up

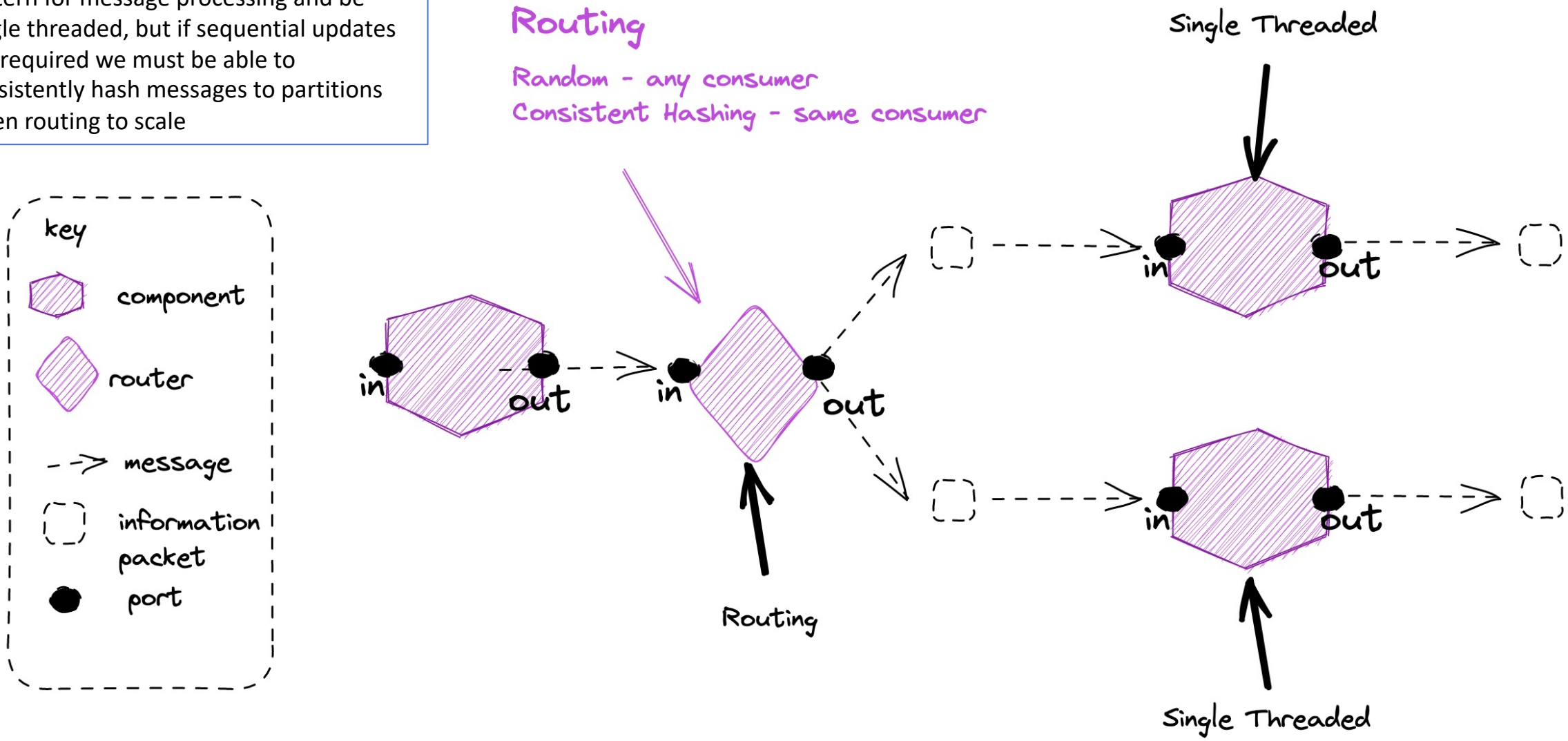
12-factor et al.



Scale Out, not Up

12-factor et al.

Single Threaded We can use the Reactor pattern for message processing and be single threaded, but if sequential updates are required we must be able to consistently hash messages to partitions when routing to scale



Agenda

T: 55

- Objects
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- Reactive
  - Reactive Programming
    - Dataflow
    - Actors
    - Flow Based Programming
    - Reactor Pattern
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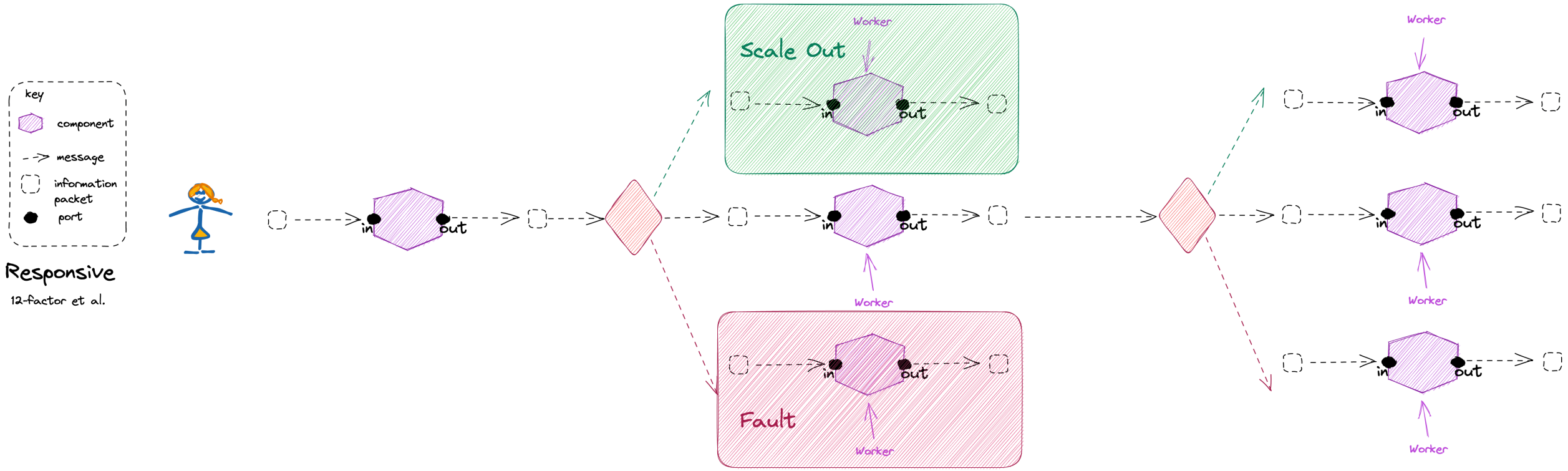
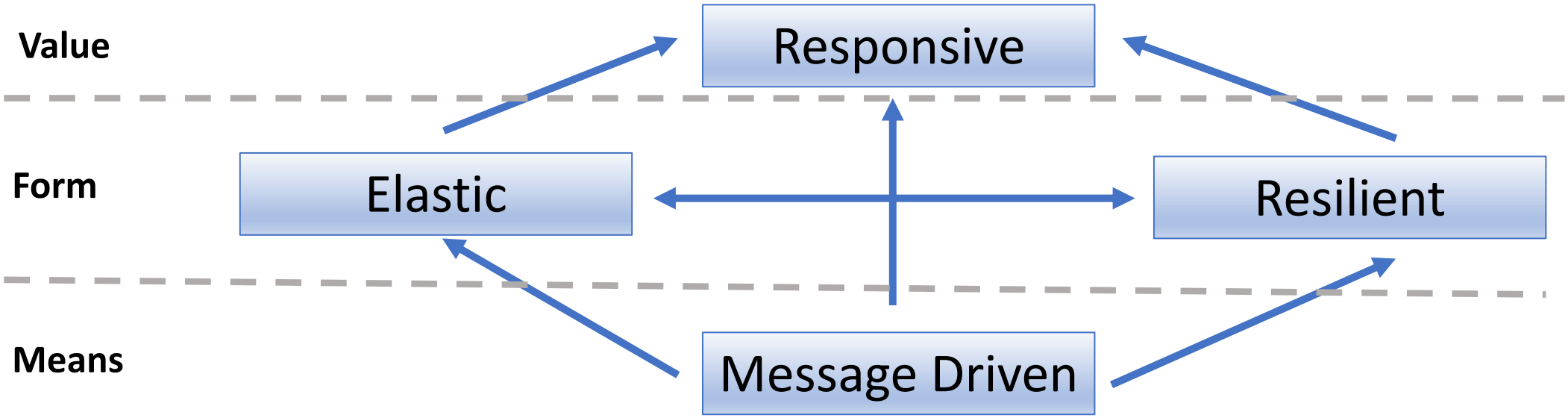

key
component
message
information packet
port
Responsive
12-factor et al.
in
out
Scale Out
Worker
Fault
Worker


Value
Responsive
Form
Elastic
Resilient
Means
Message Driven

End.