Developing event-driven microservices with event sourcing and CQRS

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http://plainoldobjects.com

http://microservices.io

EMERGING TECHNOLOGIES
FOR THE ENTERPRISE

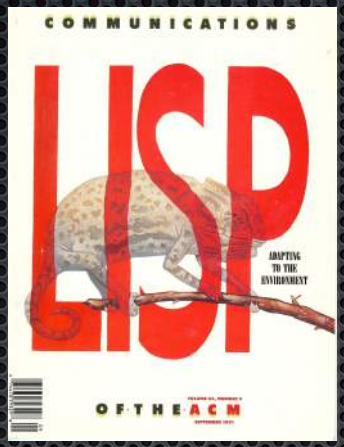
Presentation goal

Show how Event Sourcing and

Command Query Responsibility Segregation (CQRS)

are a great way to implement microservices

About Chris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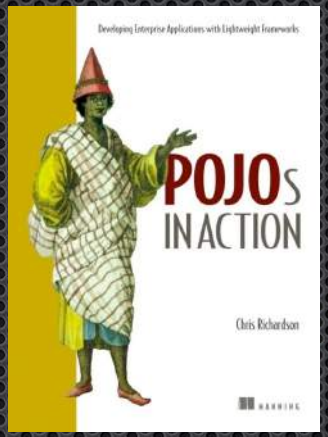
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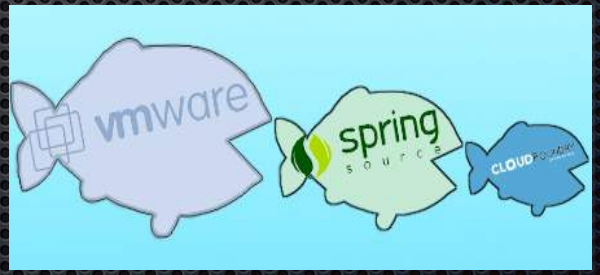
vmware
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About Chris

- Founder of a startup that's creating a platform for developing event-driven microservices
- Consultant helping organizations improve how they architect and deploy applications using cloud, micro services, polyglot applications, NoSQL, ...
- Creator of http://microservices.io

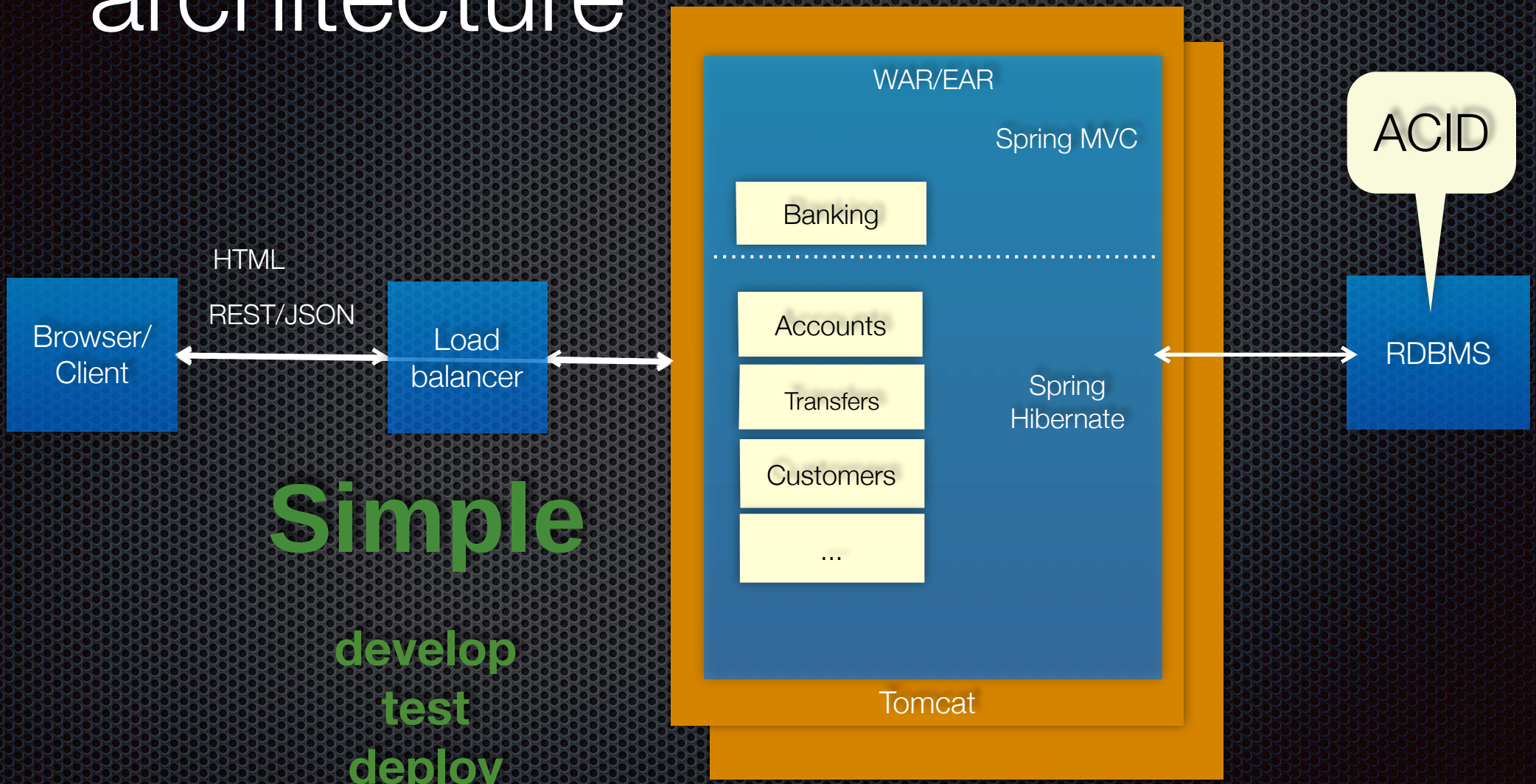
For more information

- https://github.com/cer/event-sourcing-examples
- http://microservices.io
- http://plainoldobjects.com/
- https://twitter.com/crichardson

Agenda

- Why build event-driven microservices?
- Overview of event sourcing
- Designing microservices with event sourcing
- Implementing queries in an event sourced application

Traditional application architecture



Simple

develop
test
deploy
scale

But large monolithic applications

=

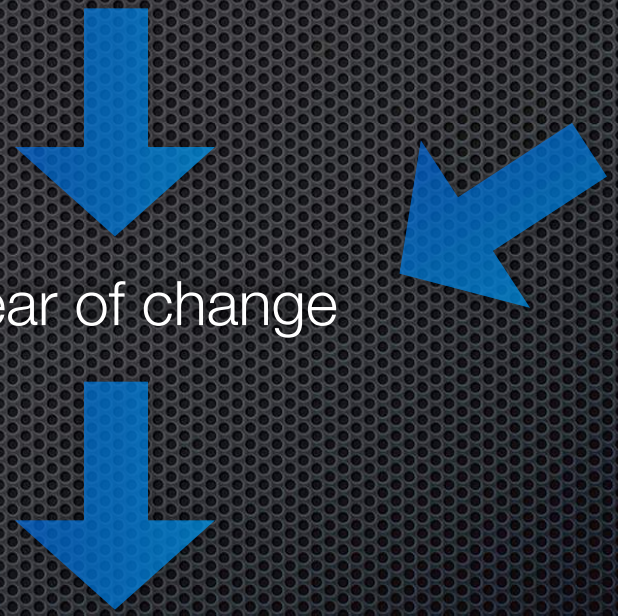
Trouble!

Intimidates developers

Obstacle to frequent deployments

- Need to redeploy everything to change one component
- Interrupts long running background (e.g. Quartz) jobs
- Increases risk of failure

Eggs in one basket

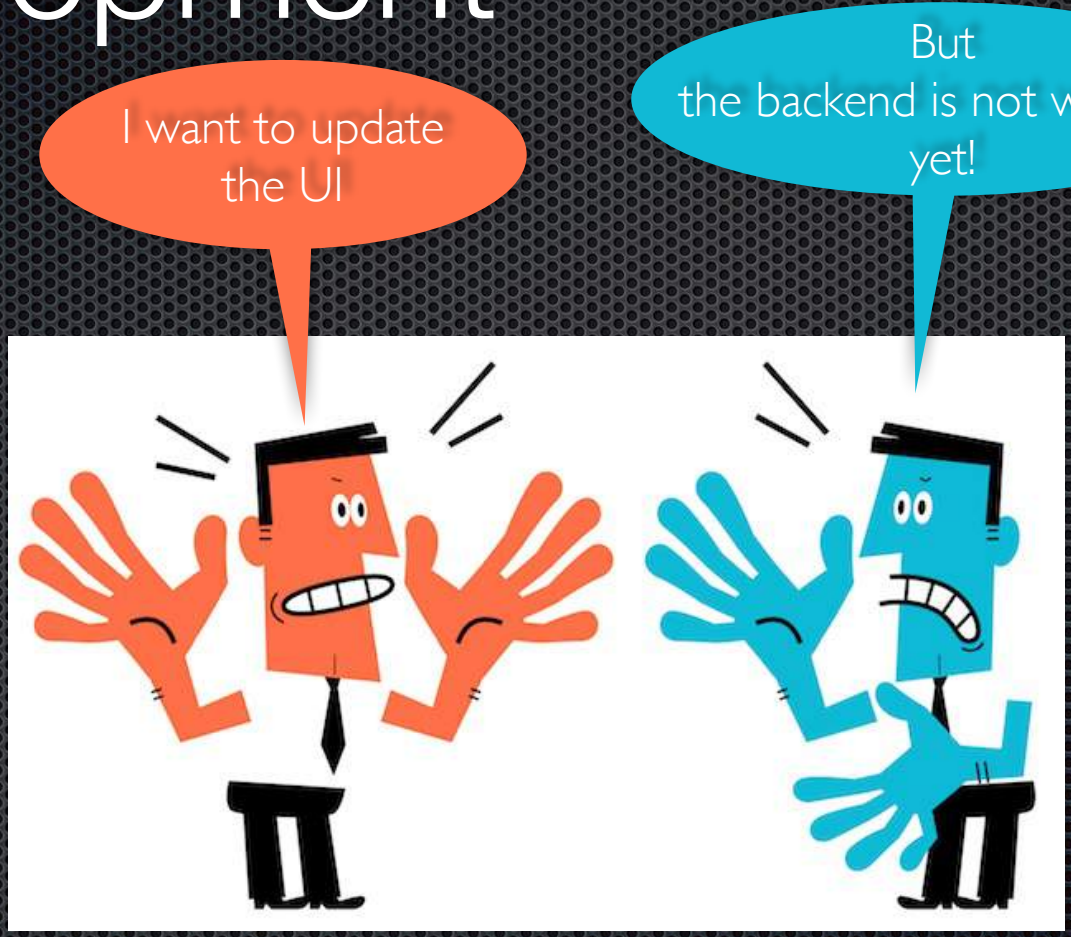


- Updates will happen less often - really long QA cycles
- e.g. Makes A/B testing UI really difficult

Overloads your IDE and container

Slows down development

Obstacle to scaling development



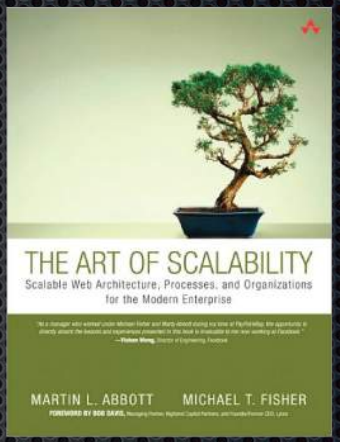
Lots of coordination and communication required

Requires long-term commitment to a technology stack

Limitations of a single relational database

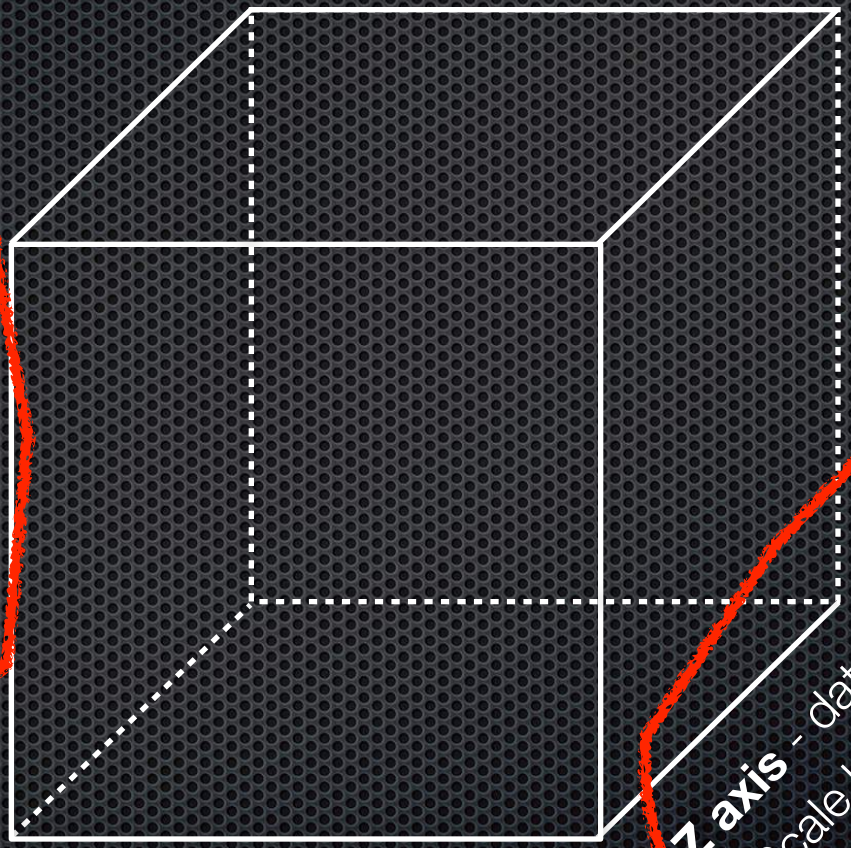
- Scalability
- Distribution
- Schema updates
- O/R impedance mismatch
- Handling semi-structured data

Apply the scale cube



Y axis - functional decomposition

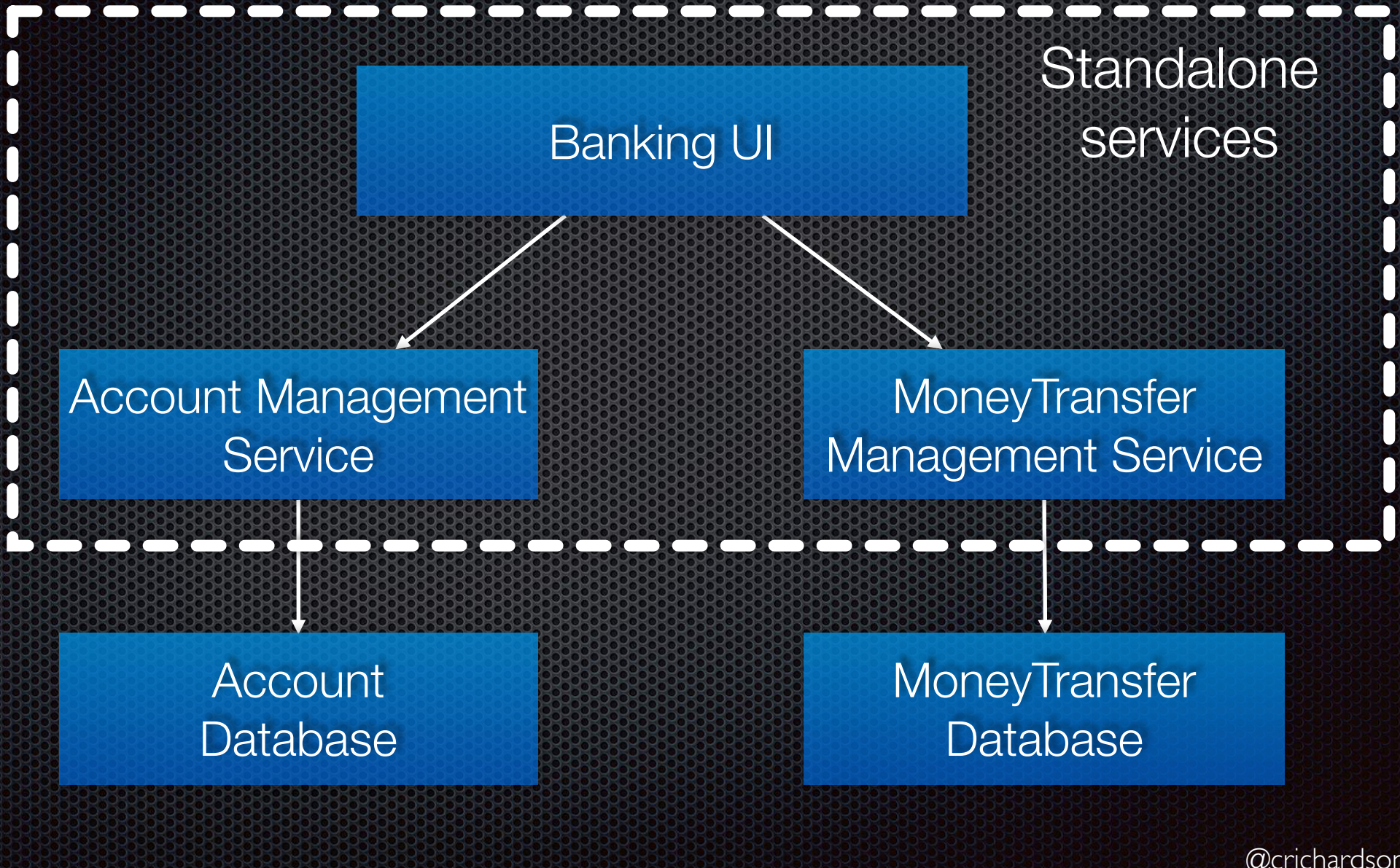
Scale by splitting different things



Z axis - data partitioning
Scale by splitting similar things

X axis
- horizontal duplication

Use a microservice architecture

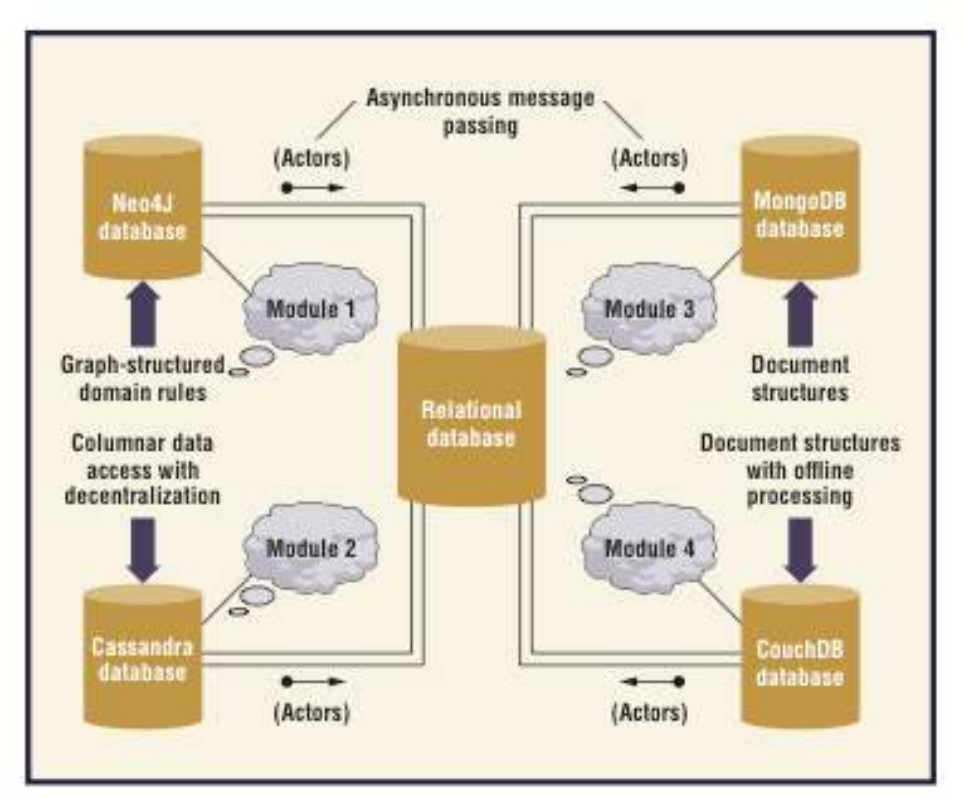


Use
functionally decomposed
and sharded
relational databases

Use NoSQL databases

- Avoids the limitations of RDBMS
- Text search ⇒ Solr/Cloud Search
- Social (graph) data ⇒ Neo4J
- Highly distributed/available database ⇒ Cassandra
- …

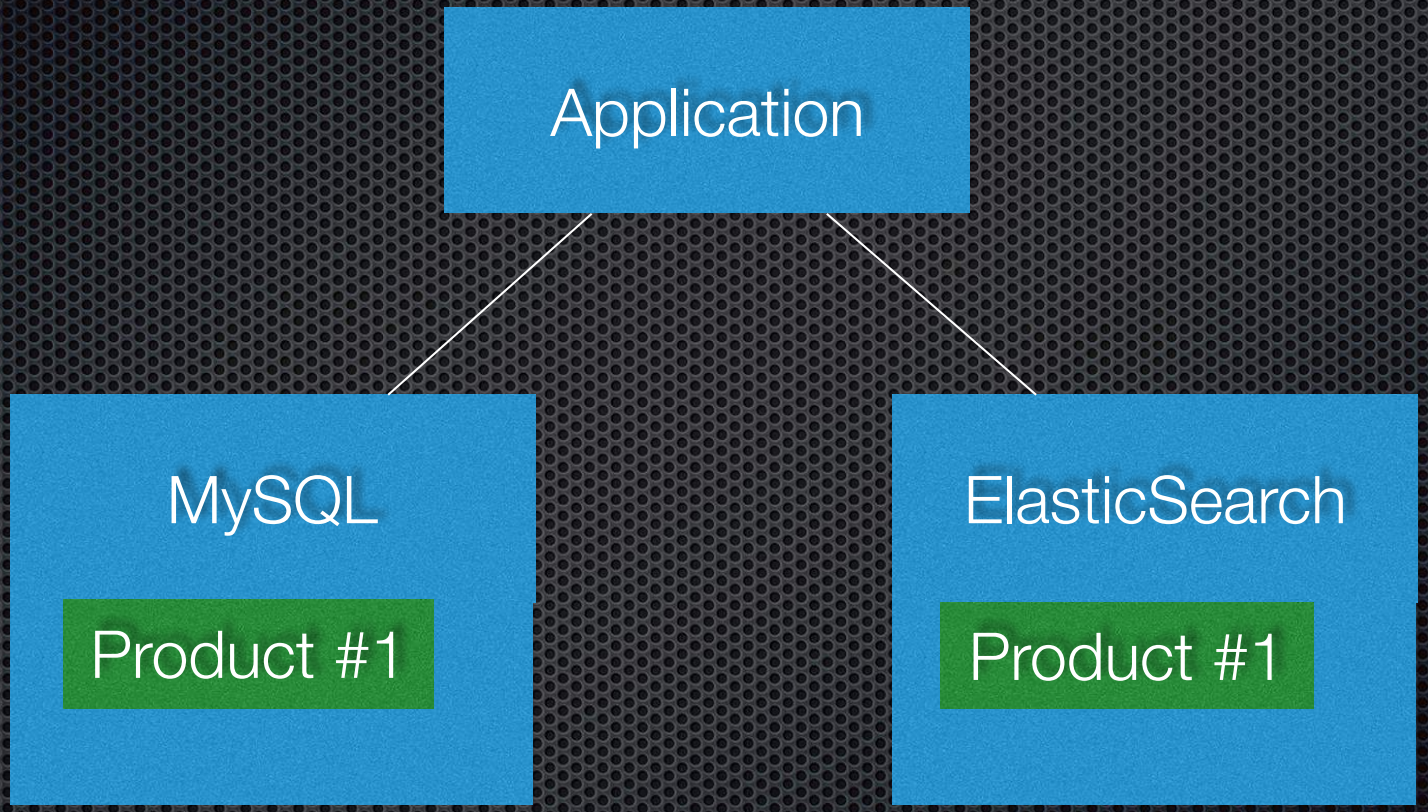
Different modules use different types of databases



IEEE Software Sept/October 2010 - Debasish Ghosh / Twitter @debasishg

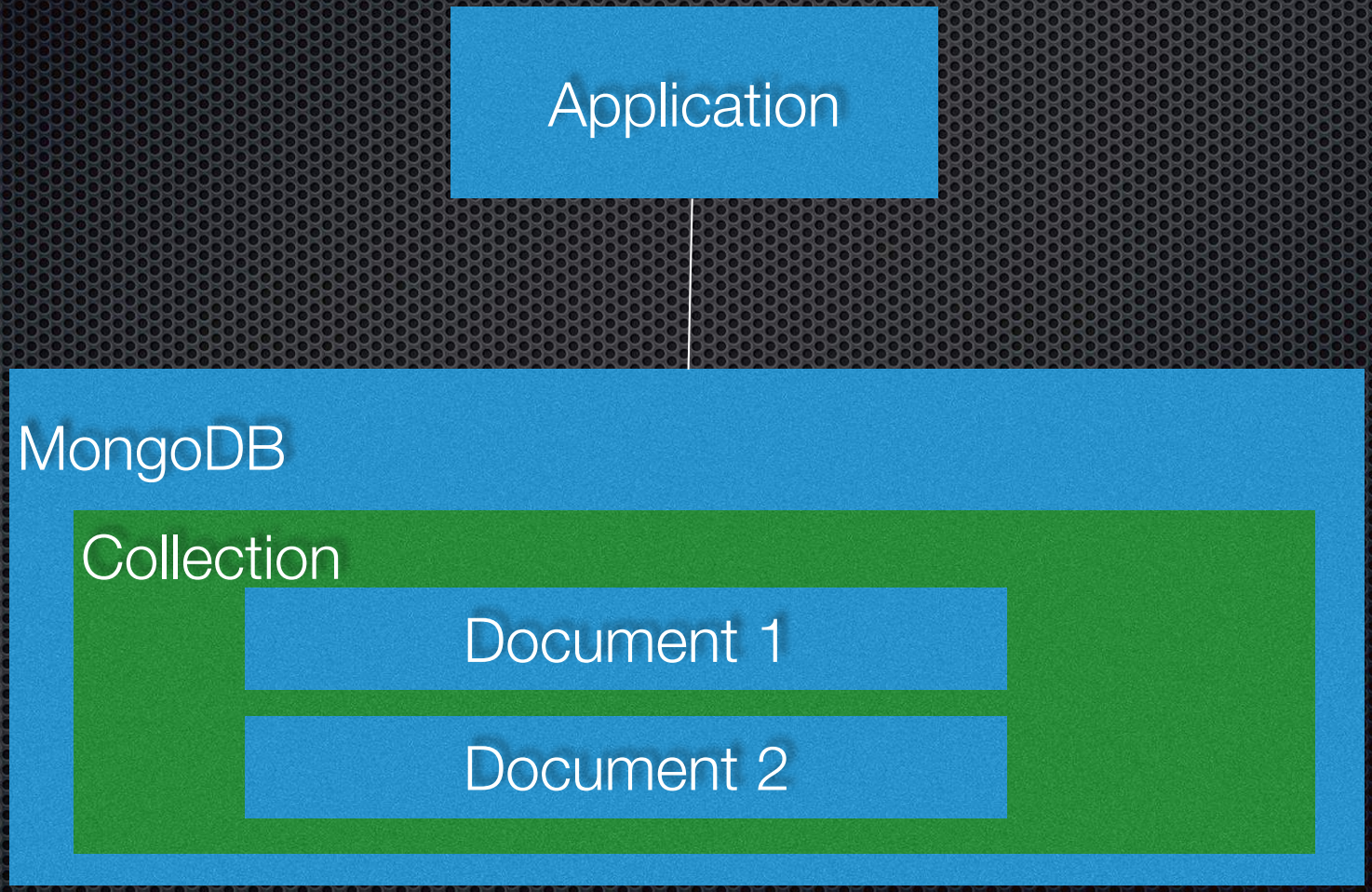
But this results in distributed data management problems

Example #1 - SQL + Text Search engine



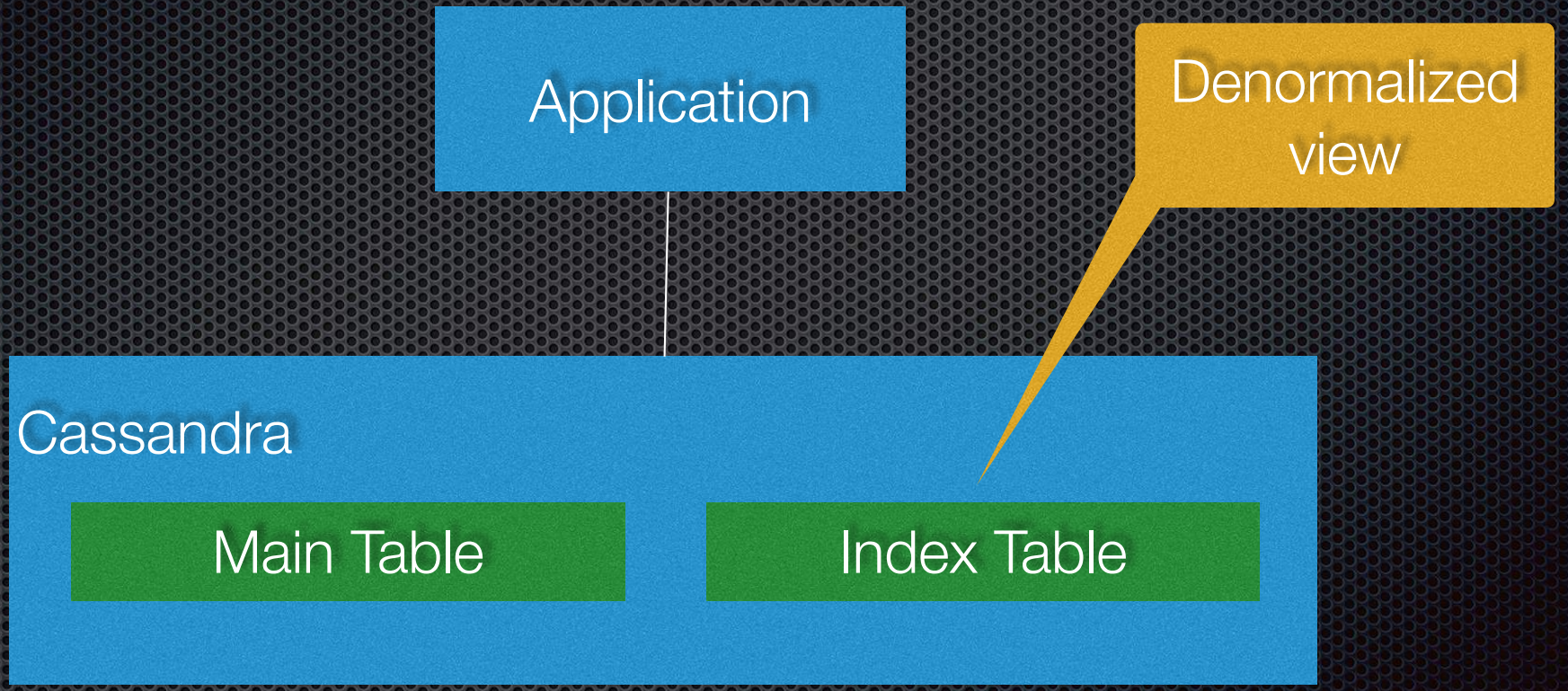
How to maintain consistency without 2PC?

Example #2 - Update two entities in a NoSQL database



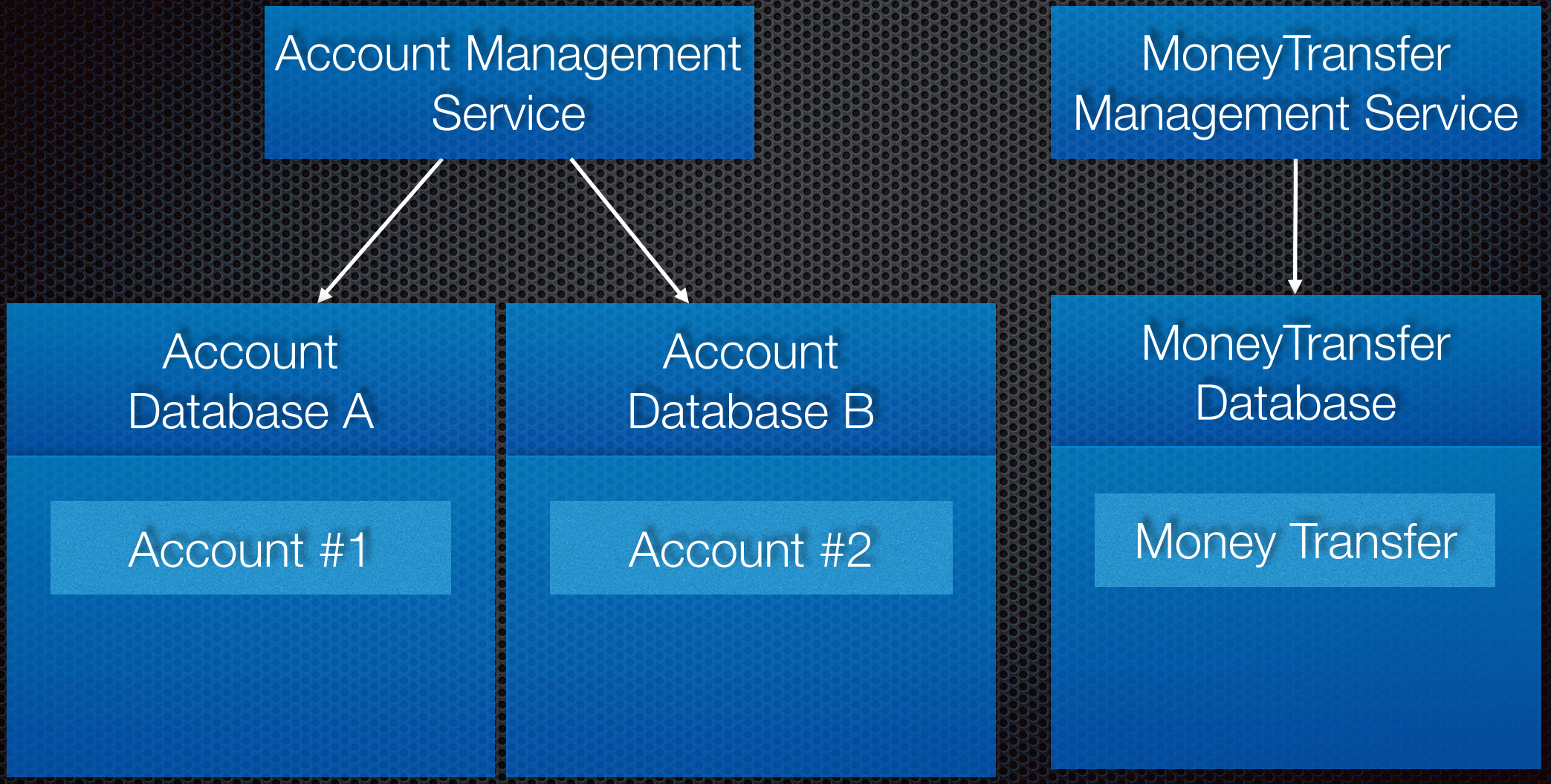
How to maintain consistency without transactions?

Example #3 - Cassandra main table <=> index table



How to maintain consistency without 2PC?

Example #4: Money transfer

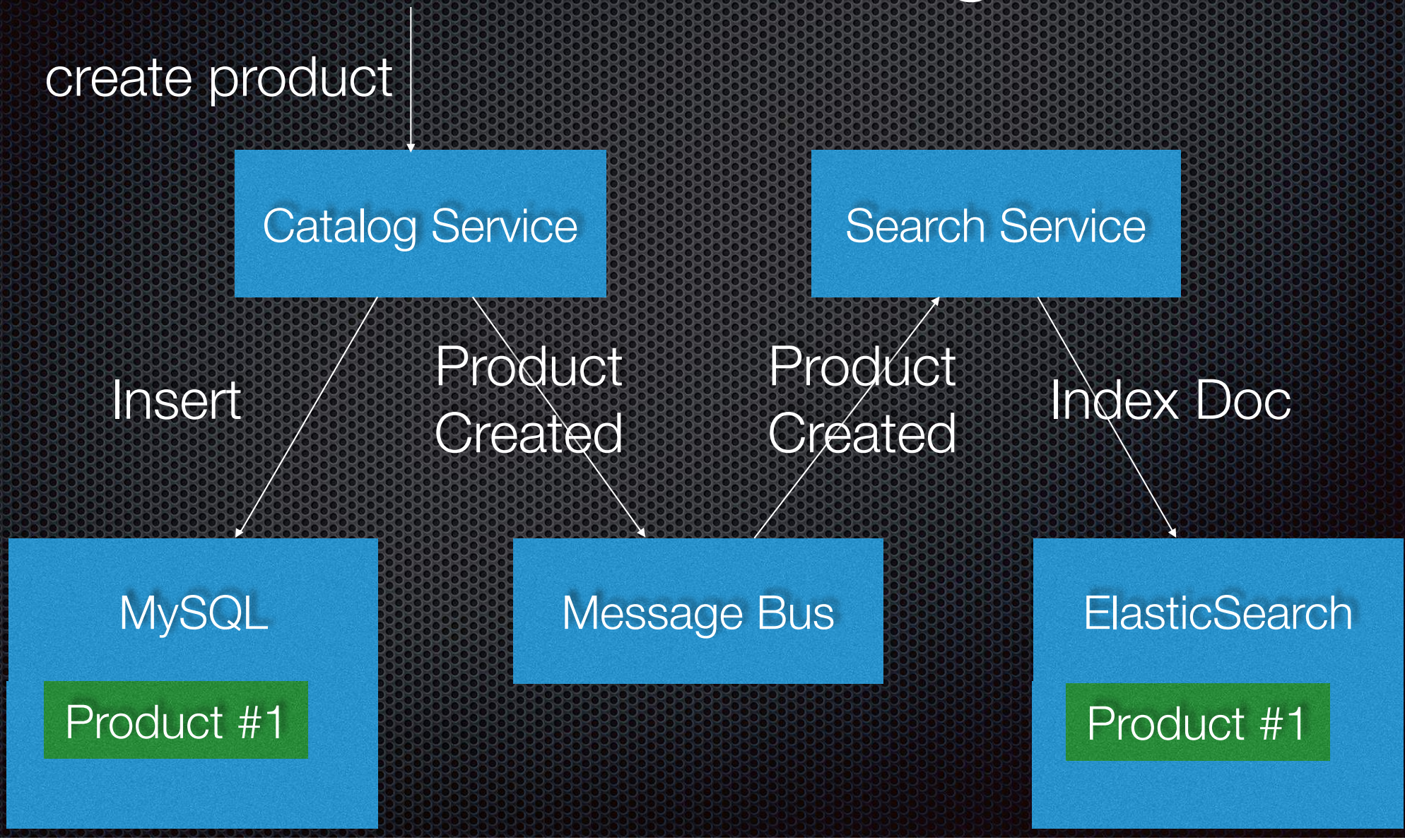


How to maintain consistency without 2PC?

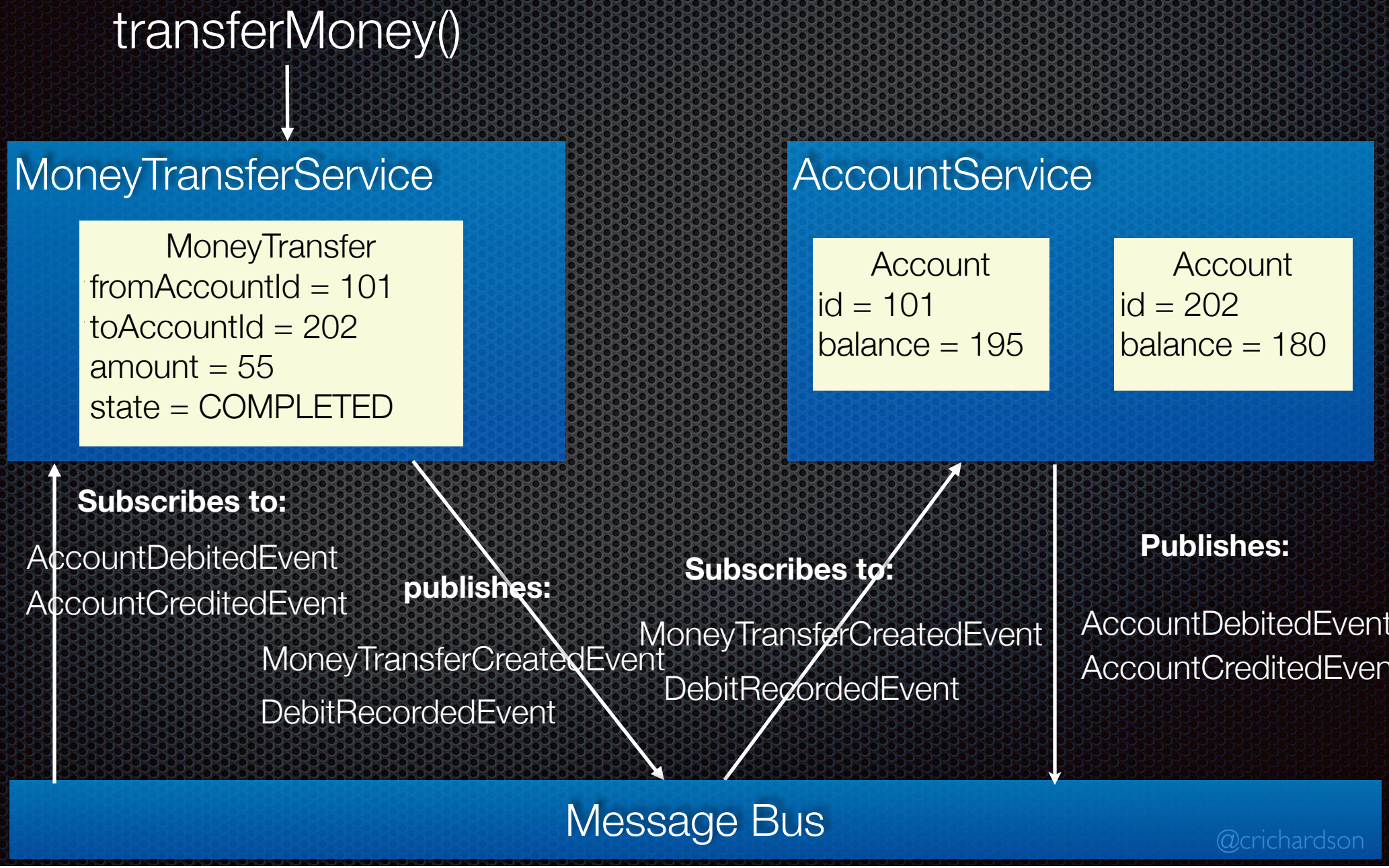
Event-based architecture to the rescue

- Components (e.g. services) publish events when state changes
- Components subscribe to events
  - Maintains eventual consistency across multiple aggregates (in multiple datastores)
  - Synchronize replicated data

Event-driven synchronization: SQL + Text Search engine



Eventually consistent money transfer



To maintain consistency
a service must
atomically publish an event
whenever
a domain object changes

How to atomically update the datastore and publish event(s)?

Update and publish using 2PC

- Guaranteed atomicity **BUT**
- Need a distributed transaction manager
- Database and message broker must support 2PC
- Impacts reliability
- Not fashionable
- 2PC is best avoided

Use data store as message queue

- Use datastore as a message queue
  - Txn #1: Update database: new entity state & event
  - Txn #2: Consume event
  - Txn #3: Mark event as consumed
- Eventually consistent mechanism (used by eBay)
- See BASE: An Acid Alternative, http://bit.ly/ebaybase
- **BUT**
- Tangled business logic and event publishing code
- Difficult to implement when using a NoSQL database :-(

Agenda

- Why build event-driven microservices?
- Overview of event sourcing
- Designing microservices with event sourcing
- Implementing queries in an event sourced application

Event sourcing

- For each aggregate in your domain model:
  - Identify (state-changing) domain events
  - Define Event classes
- For example,
  - Account: AccountOpenedEvent, AccountDebitedEvent, AccountCreditedEvent
  - ShoppingCart: ItemAddedEvent, ItemRemovedEvent, OrderPlacedEvent

Persists events NOT current state

Account table

101	450

Event table

101	901	AccountOpened	500
101	902	AccountCredited	250
101	903	AccountDebited	300

Replay events to recreate state

Events

AccountOpenedEvent(balance)
AccountDebitedEvent(amount)
AccountCreditedEvent(amount)

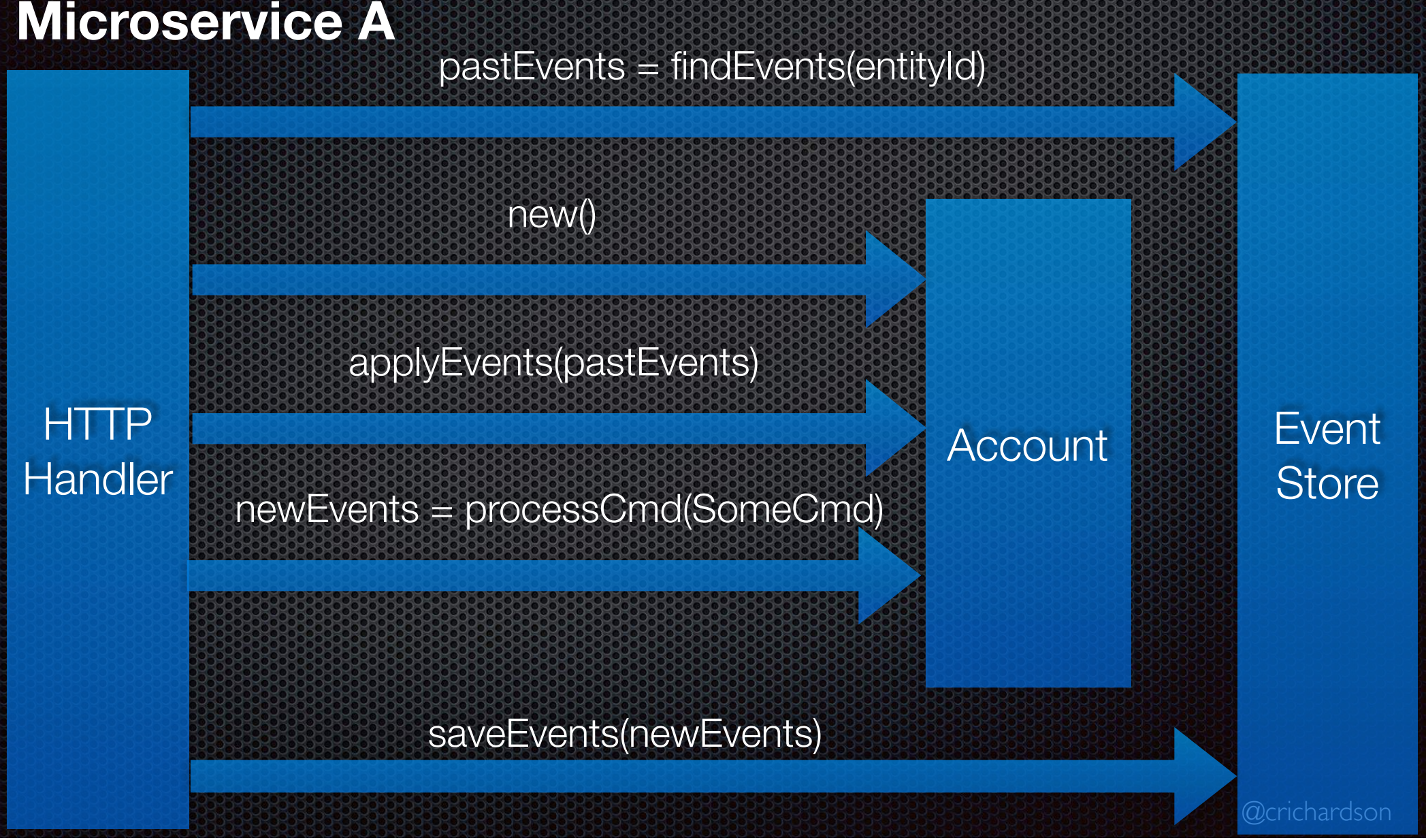
Two actions that must be atomic

Before: update state + publish events

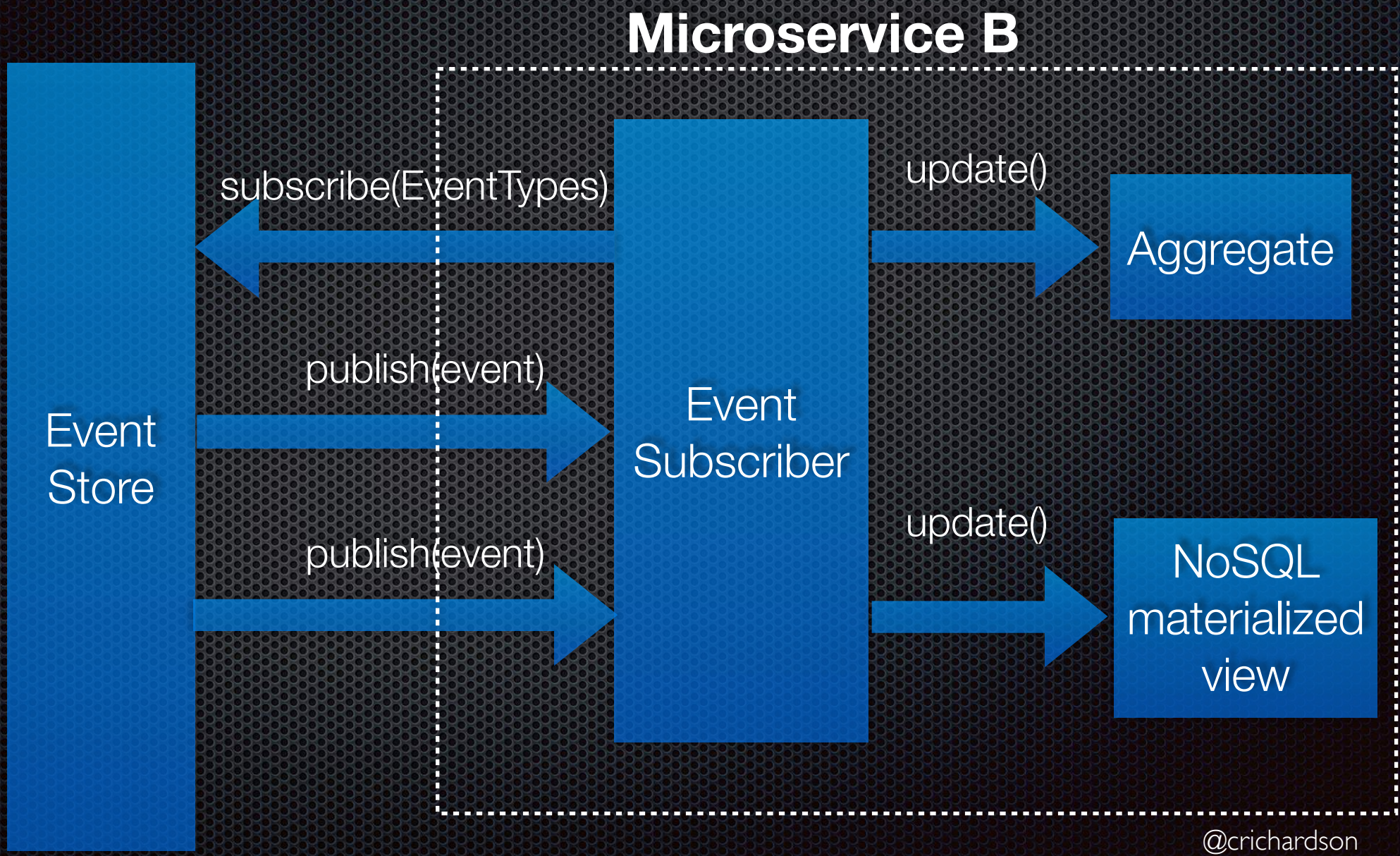
Now: persist (and publish) events

Single action that can be done atomically

Request handling in an event-sourced application



Event Store publishes events - consumed by other services



Event store implementations

- Home-grown/DIY
- geteventstore.com by Greg Young
- Talk to me about my project :-)

Optimizing using snapshots

- Most aggregates have relatively few events
- BUT consider a 10-year old Account ⇒ many transactions
- Therefore, use snapshots:
  - Periodically save snapshot of aggregate state
  - Typically serialize a memento of the aggregate
  - Load latest snapshot + subsequent events

Hybrid OO/Functional style example aggregate

Aggregate traits

Apply event returning updated Aggregate

```
trait Aggregate[T] { self : T =>
  def applyEvent(event : Event) : T
}

trait CommandProcessingAggregate[T, -CT] extends Aggregate[T] { self : T =>
  def processCommand(command : CT) : Seq[Event]
}
```

Map Command to Events

Account - command processing

```
case class Account(balance : BigDecimal)
  extends PatternMatchingCommandProcessingAggregate[Account, AccountCommand] {

  def this() = this(null)


  def processCommand = {
    case OpenAccountCommand(initialBalance) =>
      Seq(AccountOpenedEvent(initialBalance))

    case CreditAccountCommand(amount, transactionId) =>
      Seq(AccountCreditedEvent(amount, transactionId))

    case DebitAccountCommand(amount, transactionId) if amount <= balance =>
      Seq(AccountDebitedEvent(amount, transactionId))

    case DebitAccountCommand(amount, transactionId) =>
      Seq(AccountDebitFailedDueToInsufficientFundsEvent(amount, transactionId))
  }
```

Prevent overdraft

Account - applying events

Immutable

```
case class Account(balance : BigDecimal)
  extends PatternMatchingCommandProcessingAggregate[Account, AccountCommand] {

  def applyEvent = {

    case AccountOpenedEvent(initialBalance) => copy(balance = initialBalance)

    case AccountDebitedEvent(amount, _) => copy(balance = balance - amount)

    case AccountCreditedEvent(amount, _) =>
      copy(balance = balance + amount)

    case AccountDebitFailedDueToInsufficientFundsEvent(amount, _) =>
      this

  }
```

Event Store API

```
trait EventStore {

  def save[T <: Aggregate[T] : ClassTag](events: Seq[Event], assignedId: Option[EntityId] = None)
     : Future[EntityIdAndVersion]

  def update[T <: Aggregate[T] : ClassTag](entityIdAndVersion: EntityIdAndVersion, events: Seq[Event])
     : Future[EntityIdAndVersion]

  def find[T <: Aggregate[T] : ClassTag](entityId: EntityId)
     : Future[EntityWithMetadata[T]]

  def findOptional[T <: Aggregate[T] : ClassTag](entityId: EntityId)
     : Future[Option[EntityWithMetadata[T]]]
```

Reactive/Async API

Functional example aggregate

Aggregate type classes/implicits

```
trait Aggregate[T, -EV <: Event] {
  def newInstance() : T

  def applyEvent(aggregate : T, event : EV) : T

  def applyEvents(aggregate: T, events: Seq[EV]) : T =
    events.foldLeft(aggregate)(applyEvent)
}
```

```
trait Command

trait AggregateCommandProcessor[T , -CT <: Command, EV <: Event] {

  def processCommand(aggregate : T, command : CT) : Seq[EV]
}
```

Functional-style MoneyTransfer Aggregate

State

Behavior

```
case class TransferDetails(fromAccountId : EntityId, toAccountId : EntityId, amount : Money)

case class MoneyTransfer(state : TransferStates.State, details : TransferDetails)

implicit object MoneyTransferAggregate extends Aggregate[MoneyTransfer, MoneyTransferEvent]
        with AggregateCommandProcessor[MoneyTransfer, MoneyTransferCommand, MoneyTransferEvent] {

  override def newInstance() = MoneyTransfer(TransferStates.NEW, null)

  override def processCommand(mt: MoneyTransfer, command: MoneyTransferCommand): Seq[MoneyTransferEvent] =
    command match {...}

  override def applyEvent(mt: MoneyTransfer, event: MoneyTransferEvent): MoneyTransfer =
    event match {...}
```

FP-style event store

Enables inference of T, and EV

```
trait EventStore {

  def save[T, EV <: Event](clasz : Class[T], events: Seq[EV], assignedId: Option[EntityId] = None)
                          (implicit ag : Aggregate[T, EV]) :
      Future[EntityIdAndVersion]

  def update[T, EV <: Event](clasz : Class[T], entityIdAndVersion: EntityIdAndVersion, events: Seq[EV])
                           (implicit ag : Aggregate[T, EV]) :
      Future[EntityIdAndVersion]

  def find[T, EV <: Event](clasz : Class[T], entityId: EntityId)
                         (implicit ag : Aggregate[T, EV]): Future[EntityWithMetadata[T, EV]]

  def findOptional[T, EV <: Event](clasz : Class[T], entityId: EntityId)
                          (implicit ag : Aggregate[T, EV]): Future[Option[EntityWithMetadata[T, EV]]]
}
```

Tells ES how to instantiate aggregate and apply events

Business benefits of event sourcing

- Built-in, reliable audit log
- Enables temporal queries
- Publishes events needed by big data/predictive analytics etc.
- Preserved history ⇒ More easily implement future requirements

Technical benefits of event sourcing

- Solves data consistency issues in a Microservice/NoSQL-based architecture:
  - Atomically save and publish events
  - Event subscribers update other aggregates ensuring eventual consistency
  - Event subscribers update materialized views in SQL and NoSQL databases (more on that later)
- Eliminates O/R mapping problem

Drawbacks of event sourcing

- Weird and unfamiliar
- Events = a historical record of your bad design decisions
- Handling duplicate events can be tricky
- Application must handle eventually consistent data
- Event store only directly supports PK-based lookup (more on that later)

Agenda

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- Overview of event sourcing
- Designing microservices with event sourcing
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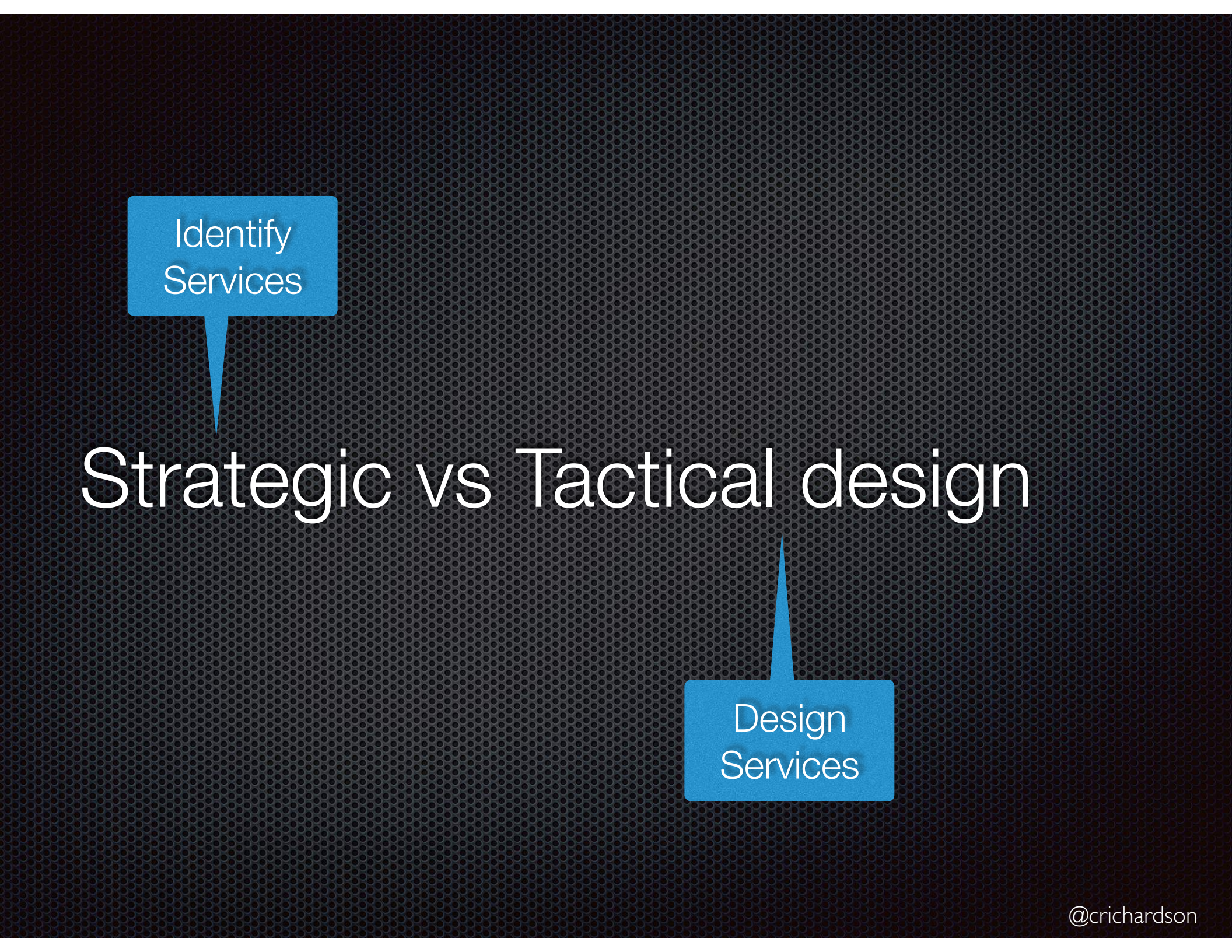
Identify Services
Strategic vs Tactical design
Design Services
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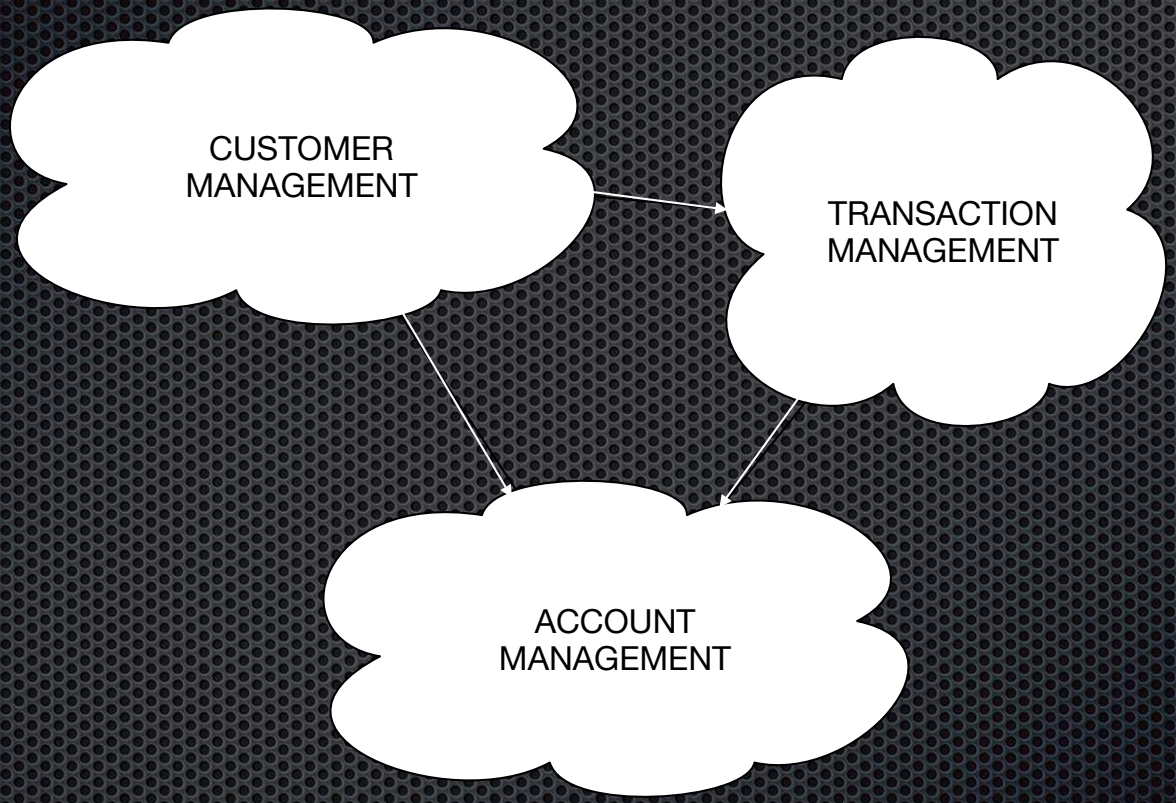
Strategic design
and
Greenfield development

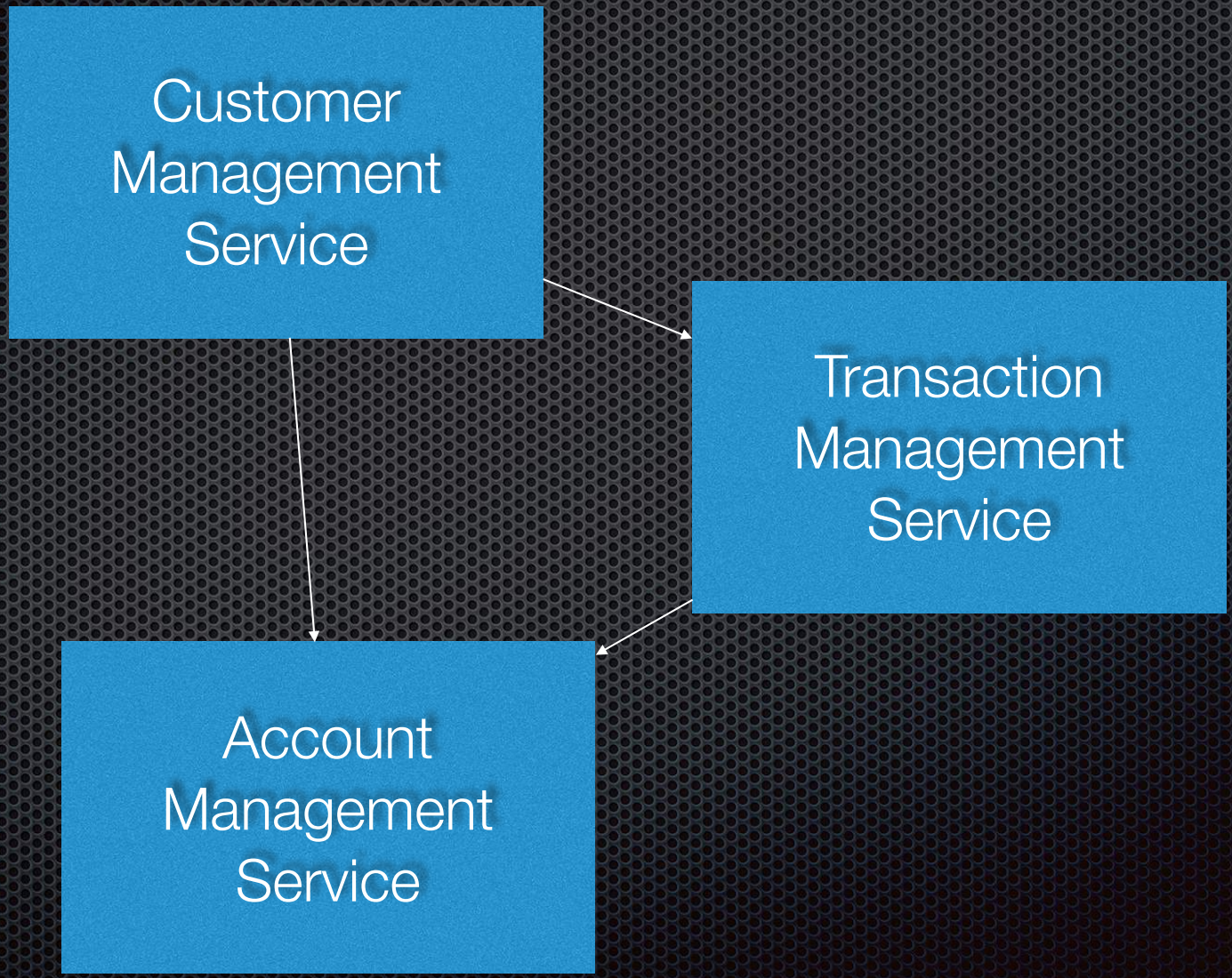
Strategic design: identify sub-domains

Strategic design: identify sub-domains

Strategic design: identify bounded contexts



Strategic design: define microservices

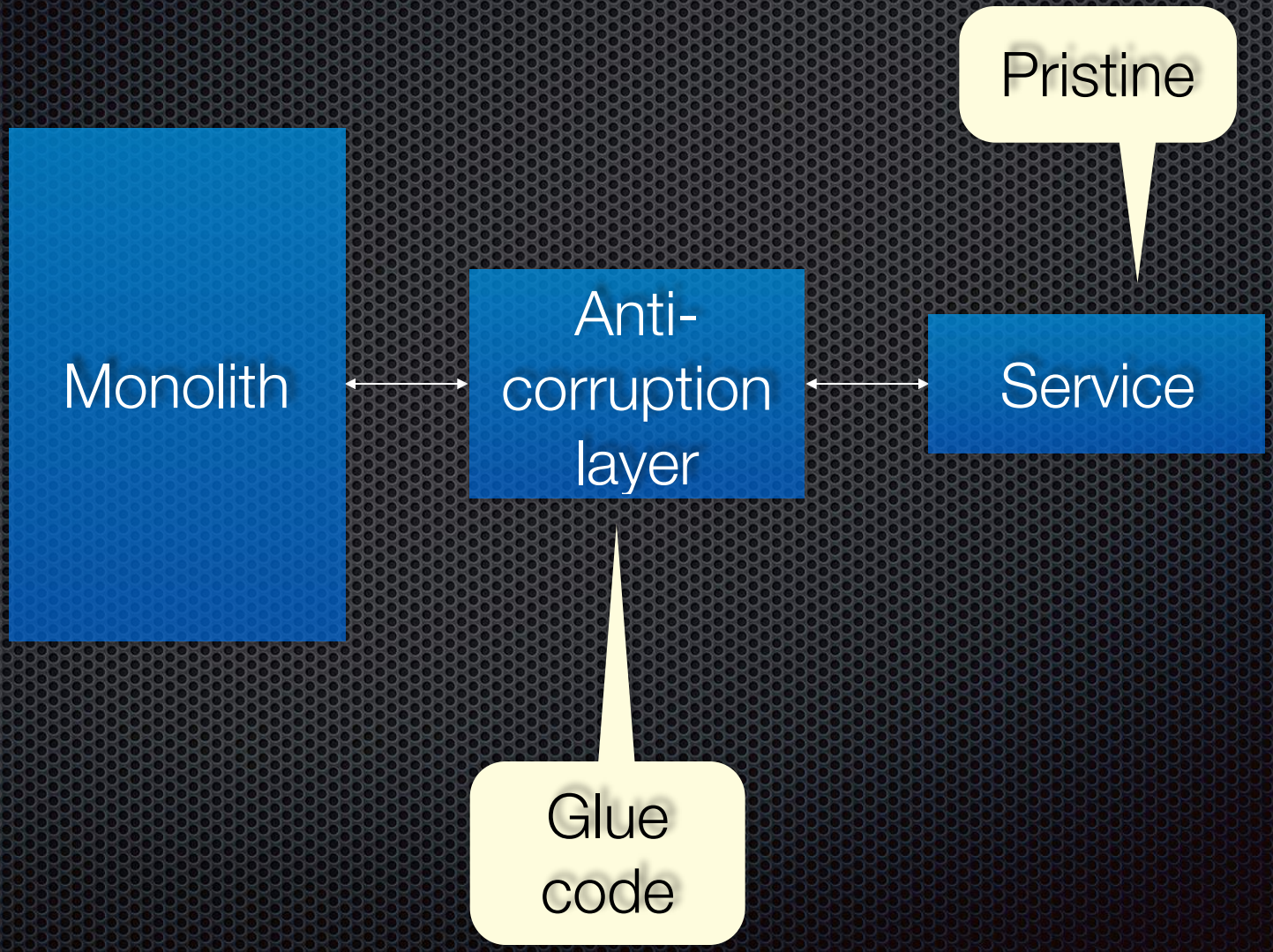


Decide inter-service communication mechanisms

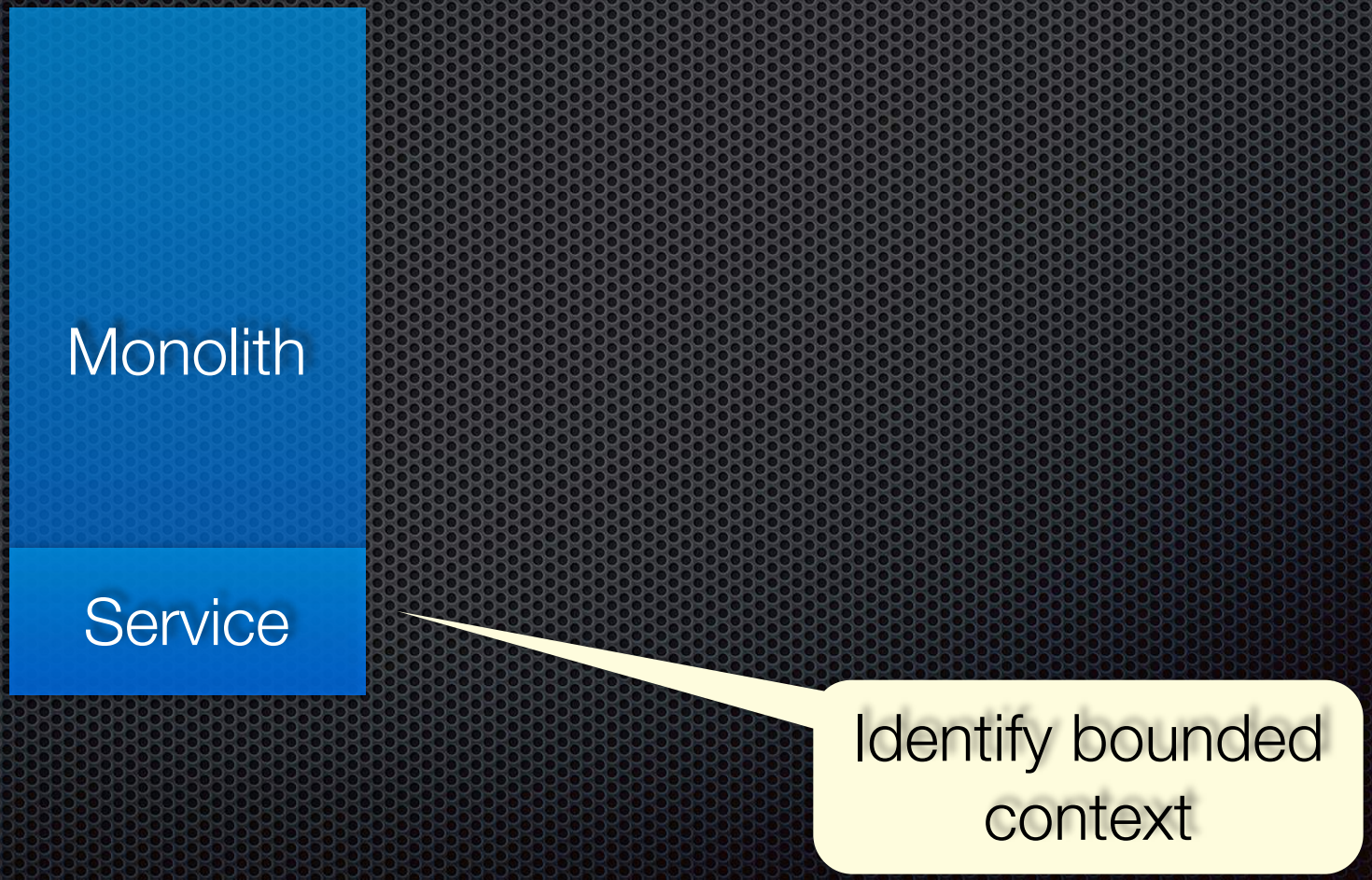
- Service X reads from service Y
  - X makes an RPC call to Y
  - X consumes events published by Y
- Service X updates service Y
  - ~~X makes an RPC call to Y~~ <= unreliable without 2PC
  - Y consumes events published by X

Strategic design
and
refactoring a monolith

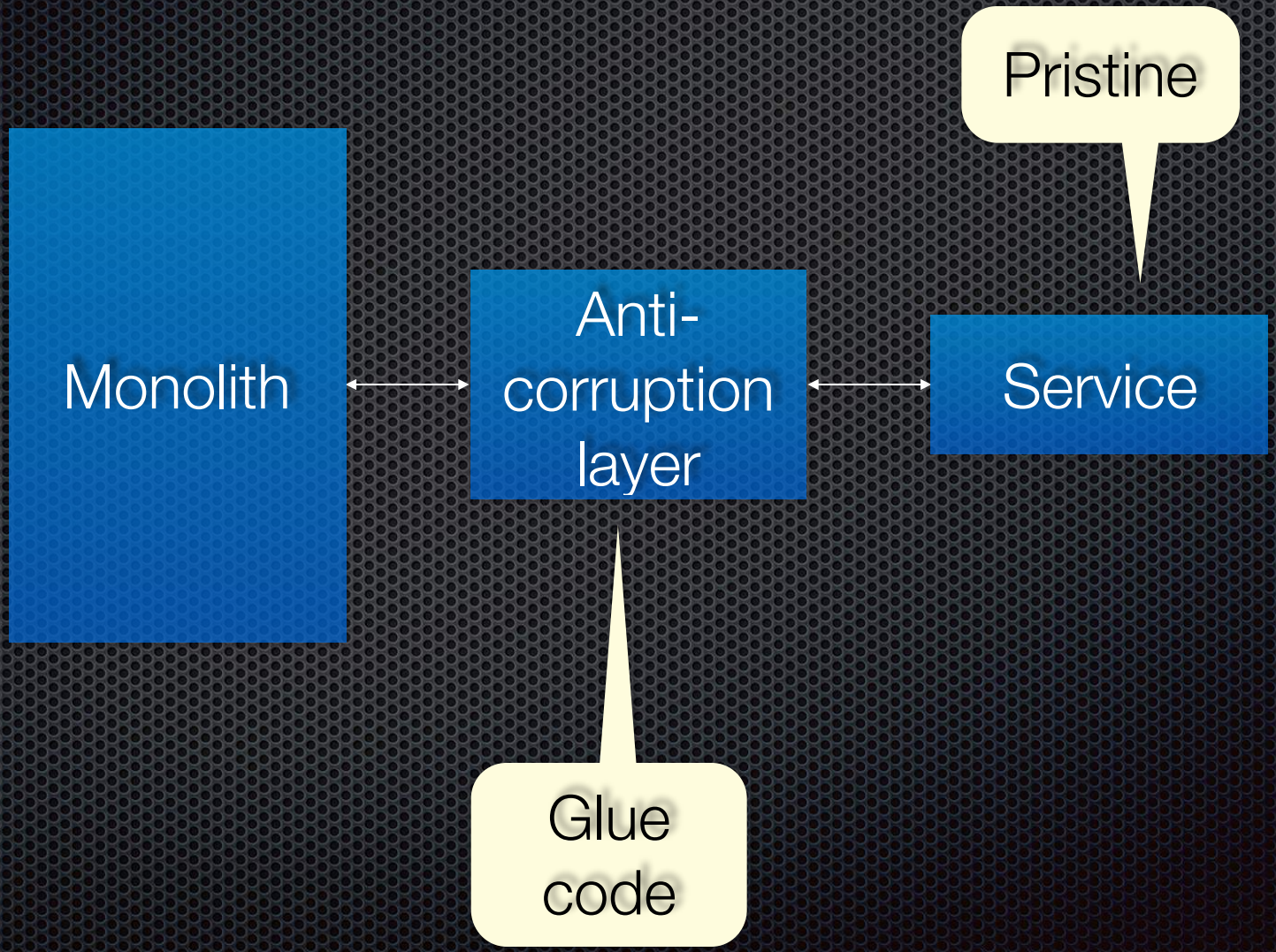
Existing monolith: implement new functionality as a service



Existing monolith: extract functionality as a service



Existing monolith: extract functionality as a service



Tactical design

Use the familiar building blocks of DDD

- Entity
- Value object
- Services
- Repositories

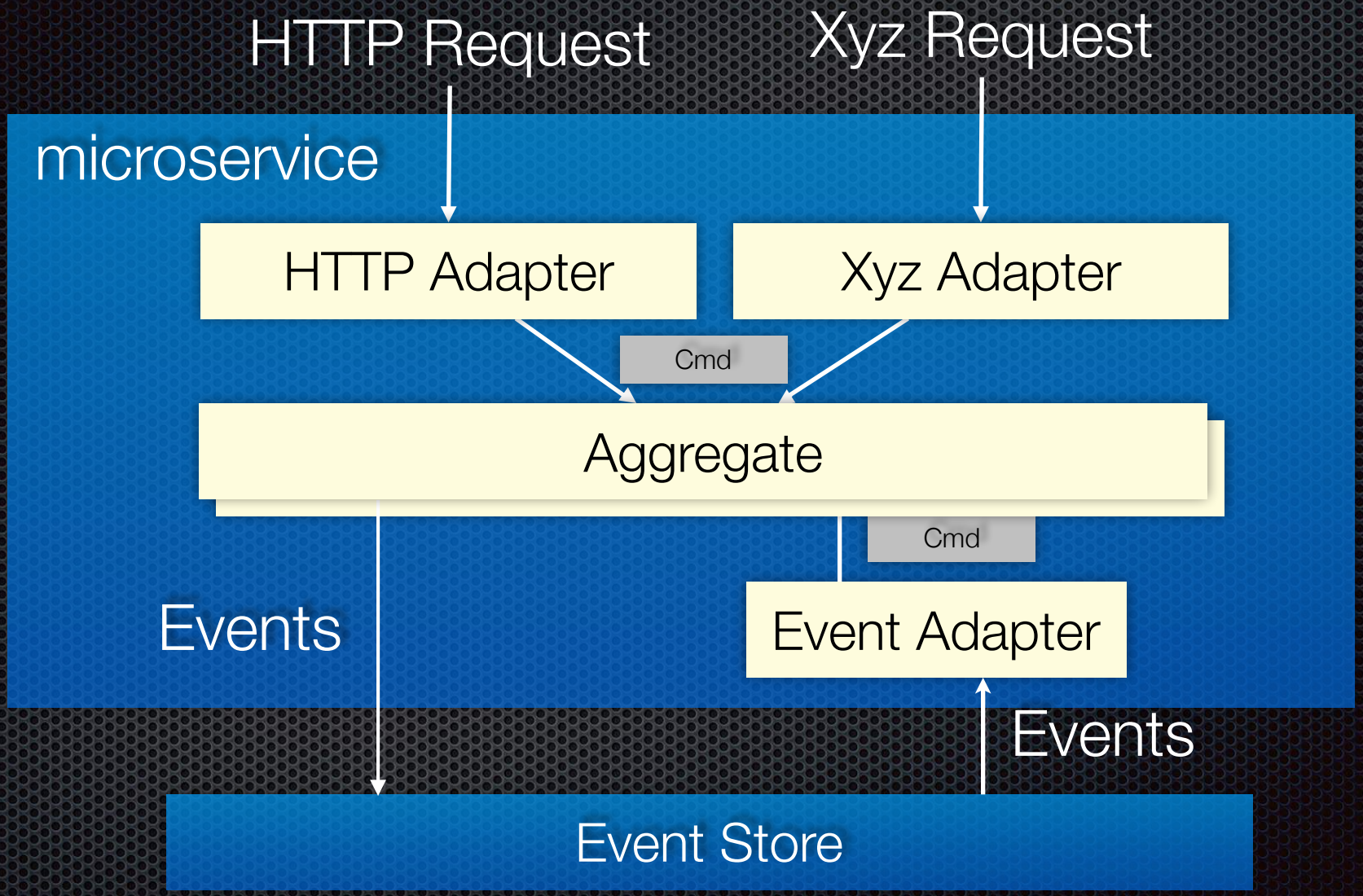
Partition a bounded context's domain model into Aggregates

Identify the state changing events for each Aggregate

Designing domain events

- Naming
  - Past tense to reflect that something occurred
  - Ideally specific: AccountOpened/Debited/Credited
  - Sometimes vague: FooUpdated
- Event attributes
  - Id - TimeUUID
  - Other attributes - from command, required to persist entity
- Event enrichment
  - ProductAddedToCart(**productId**) vs. ProductAddedCart(**productInfo**)
  - Extra data to support event consumers

The anatomy of a microservice



Asynchronous Spring MVC controller

```
@RestController
class MoneyTransferController @Autowired()(moneyTransferService : MoneyTransferService,
                                            eventStore : EventStore) {

  @RequestMapping(value=Array("/transfers"), method = Array(RequestMethod.POST))
  def create(@RequestBody transferDetails : TransferDetails) = WebUtil.toDeferredResult {
    for (transaction <- moneyTransferService.transferMoney(transferDetails))
      yield CreateMoneyTransferResponse(transaction.entityId.id)
  }
```

Scala Future => Spring MVC DeferredResult

MoneyTransferService

```
class MoneyTransferService(implicit eventStore : EventStore) {

  def transferMoney(transferDetails : TransferDetails) =
    newEntity[MoneyTransfer] <== CreateMoneyTransferCommand(transferDetails)

}
```

DSL concisely specifies:

1. Creates MoneyTransfer aggregate
2. Processes command
3. Applies events
4. Persists events

Handling events published by Accounts

```
@EventSubscriber (id = "transactionEventHandlers")
class MoneyTransferEventHandlers(implicit eventStore: EventStore)
  extends CompoundEventHandler {

  val recordDebit =
    handlerForEvent[AccountDebitedEvent] { de =>
      existingEntity[MoneyTransfer](de.event.transactionId) <==
        RecordDebitCommand(de.entityId)
    }
```

1. Load MoneyTransfer aggregate
2. Processes command
3. Applies events
4. Persists events

Agenda

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Let's imagine that you want to display an account and it's recent transactions...

Displaying balance + recent credits and debits

- We need to do a “join: between the Account and the corresponding MoneyTransfers
- (Assuming Debit/Credit events don’t include other account, ...)

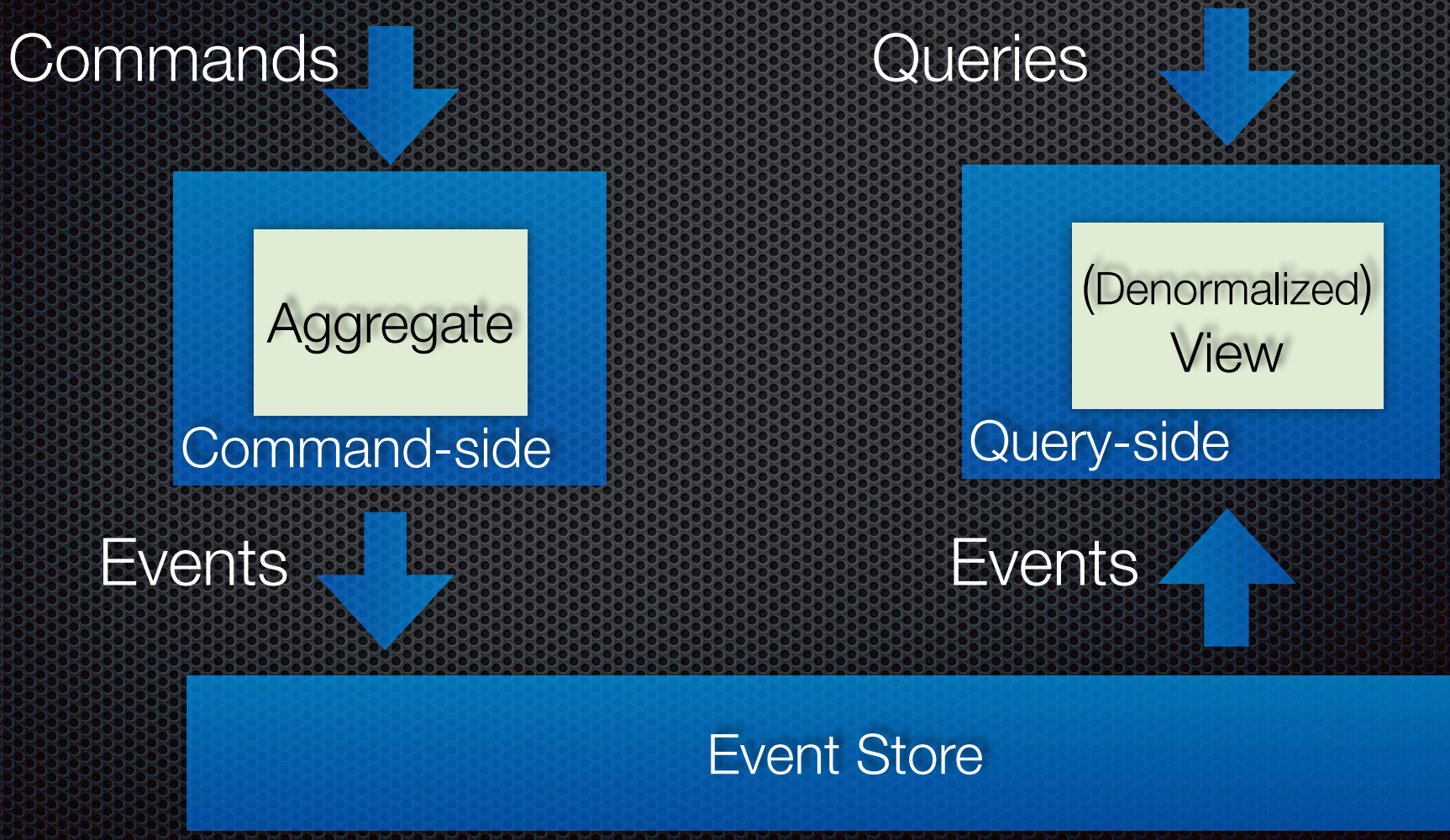
BUT

- Event Store = primary key lookup of individual aggregates, ...

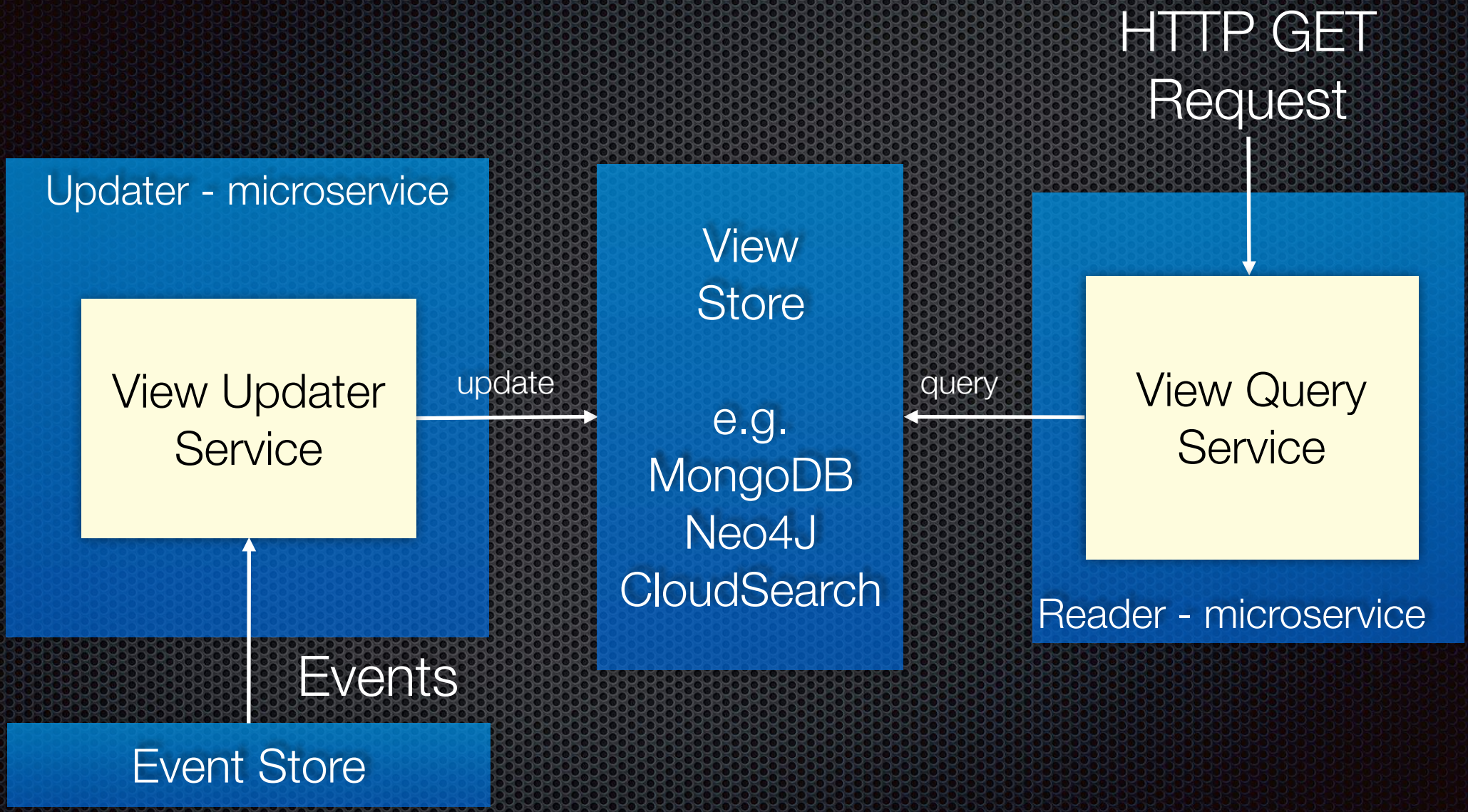
⇒

- Use **C**ommand **Q**uery **R**esponsibility **S**egregation

Command Query Responsibility Segregation (CQRS)



Query-side microservices



Persisting account balance and recent transactions in MongoDB

```
{
   id: "298993498",
   balance: 100000,
   transfers : [
      {"transferId" : "455284094848 4",
       "fromAccountId" : 298993498,
       "toAccountId" : 3483948934,
       "amount" : 5000}, ...
   ],
   changes: [
     {"changeId" : "93843948934",
      "transferId" : "455284094848 4",
      "transactionType" : "AccountDebited",
      "amount" : 5000}, ...
   ]
}
```

Current balance

MoneyTransfers that update the account

The debits and credits

Denormalized = efficient lookup

@crichardson

Persisting account info using MongoDB...

```
class AccountInfoUpdateService
    (accountInfoRepository : AccountInfoRepository, mongoTemplate : MongoTemplate)
          extends CompoundEventHandler {


  @EventHandlerMethod
  def created(de: DispatchedEvent[AccountOpenedEvent]) = …

  @EventHandlerMethod
  def recordDebit(de: DispatchedEvent[AccountDebitedEvent]) = …

  @EventHandlerMethod
  def recordCredit(de: DispatchedEvent[AccountCreditedEvent]) = …

  @EventHandlerMethod
  def recordTransfer(de: DispatchedEvent[MoneyTransferCreatedEvent]) = …


}
```

Other kinds of views

- AWS Cloud Search
  - Text search as-a-Service
  - View updater batches aggregates to index
  - View query service does text search
- AWS DynamoDB
  - NoSQL as-a-Service
  - On-demand scalable - specify desired read/write capacity
  - Document and key-value data models
  - Useful for denormalized, UI oriented views

Benefits and drawbacks of CQRS

Benefits

- Necessary in an event-sourced architecture
- Separation of concerns = simpler command and query models
- Supports multiple denormalized views
- Improved scalability and performance

Drawbacks

- Complexity
- Potential code duplication
- Replication lag/eventually consistent views

Summary

- Event sourcing solves key data consistency issues with:
  - Microservices
  - Partitioned SQL/NoSQL databases
- Apply strategic DDD to identify microservices
- Apply tactical DDD to design individual services
- Use CQRS to implement materialized views for queries

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http://plainoldobjects.com http://microservices.io