Building and deploying microservices with event sourcing, CQRS and Docker

Chris Richardson

Author of POJOs in Action

Founder of the original CloudFoundry.com

@crichardson

chris@chrisrichardson.net

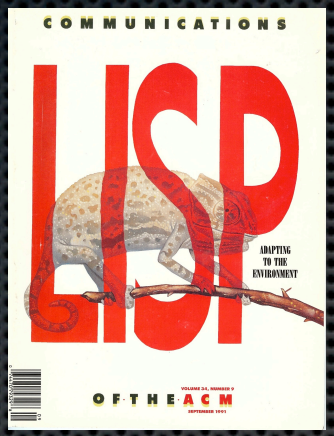
http://plainoldobjects.com

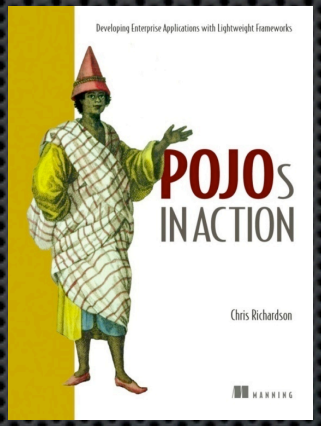
QCon SAN FRANCISCO

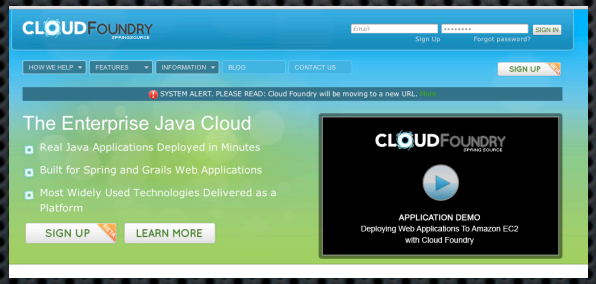
Presentation goal

Share my experiences with building and deploying an application using Scala, functional domain models, microservices, event sourcing, CQRS, and Docker

About Chris







@crichardson

About Chris

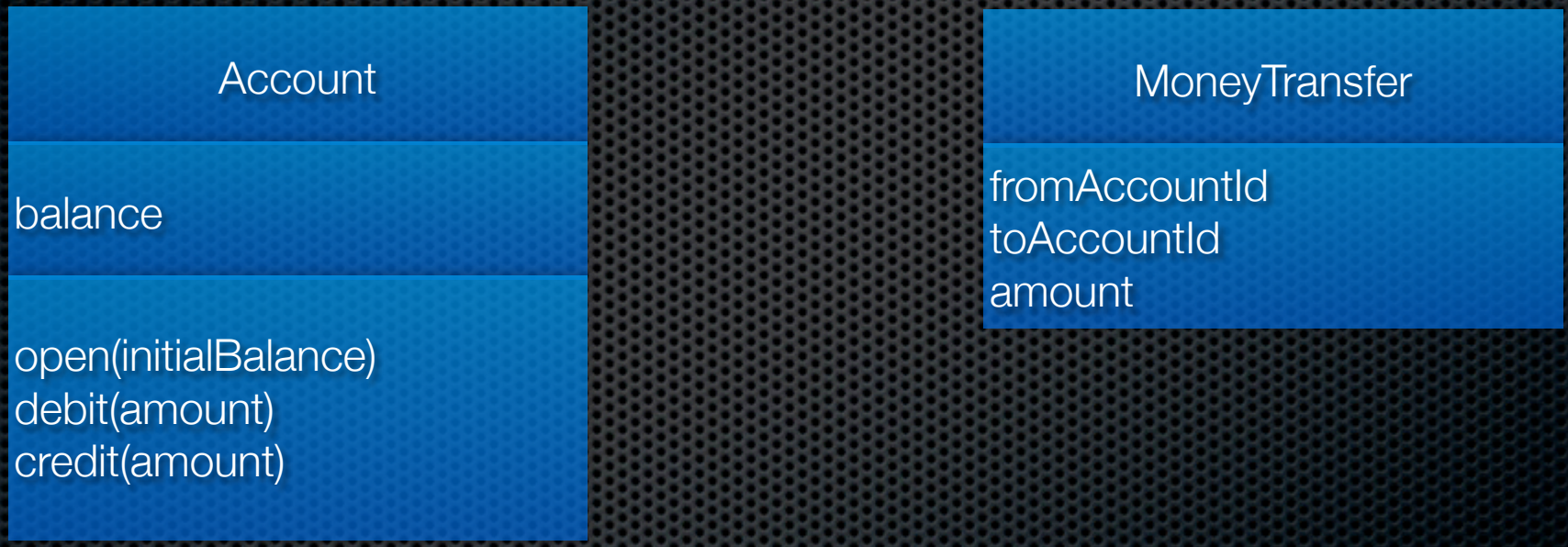
- Founder of a buzzword compliant (stealthy, social, mobile, big data, machine learning, ...) startup
- Consultant helping organizations improve how they architect and deploy applications using cloud, micro services, polyglot applications, NoSQL, ...
- Creator of http://microservices.io

Agenda

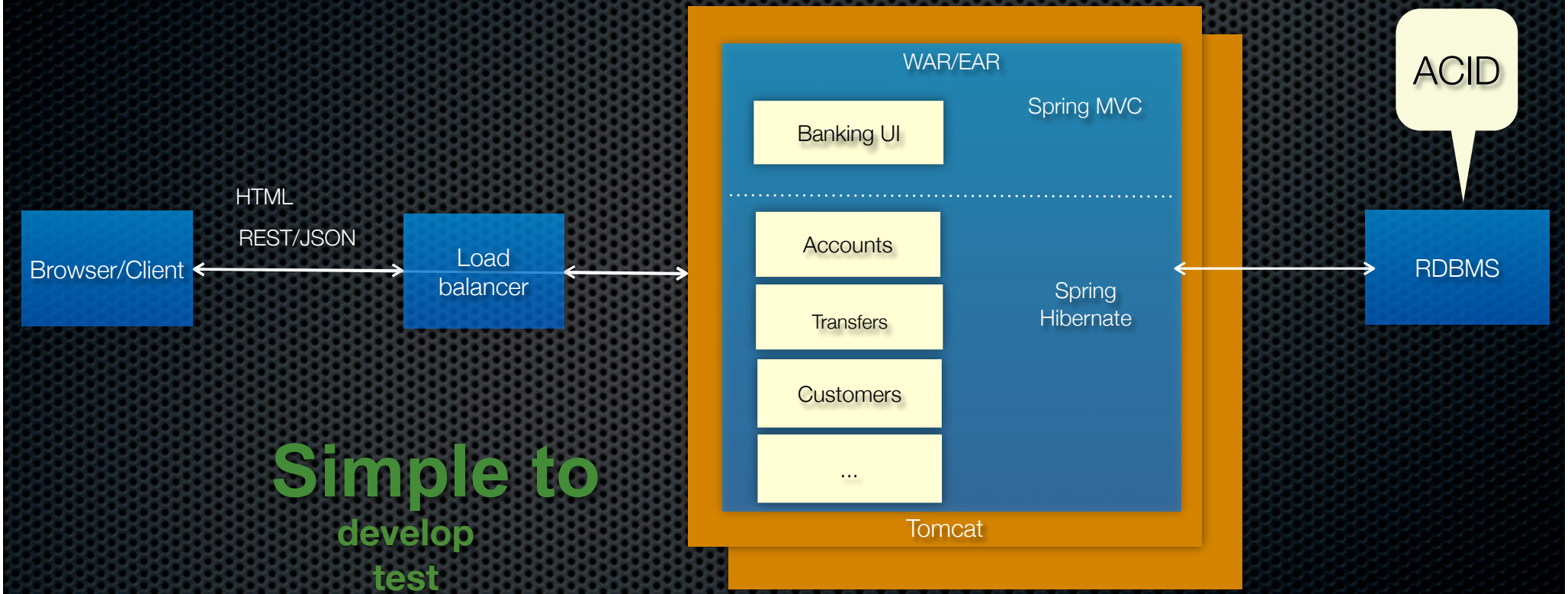
- Why build event-driven microservices?
- Overview of event sourcing
- Designing microservices with event sourcing
- Implementing queries in an event sourced application
- Building and deploying microservices

Let’s imagine that you are building a banking app...

Domain model



Traditional application architecture



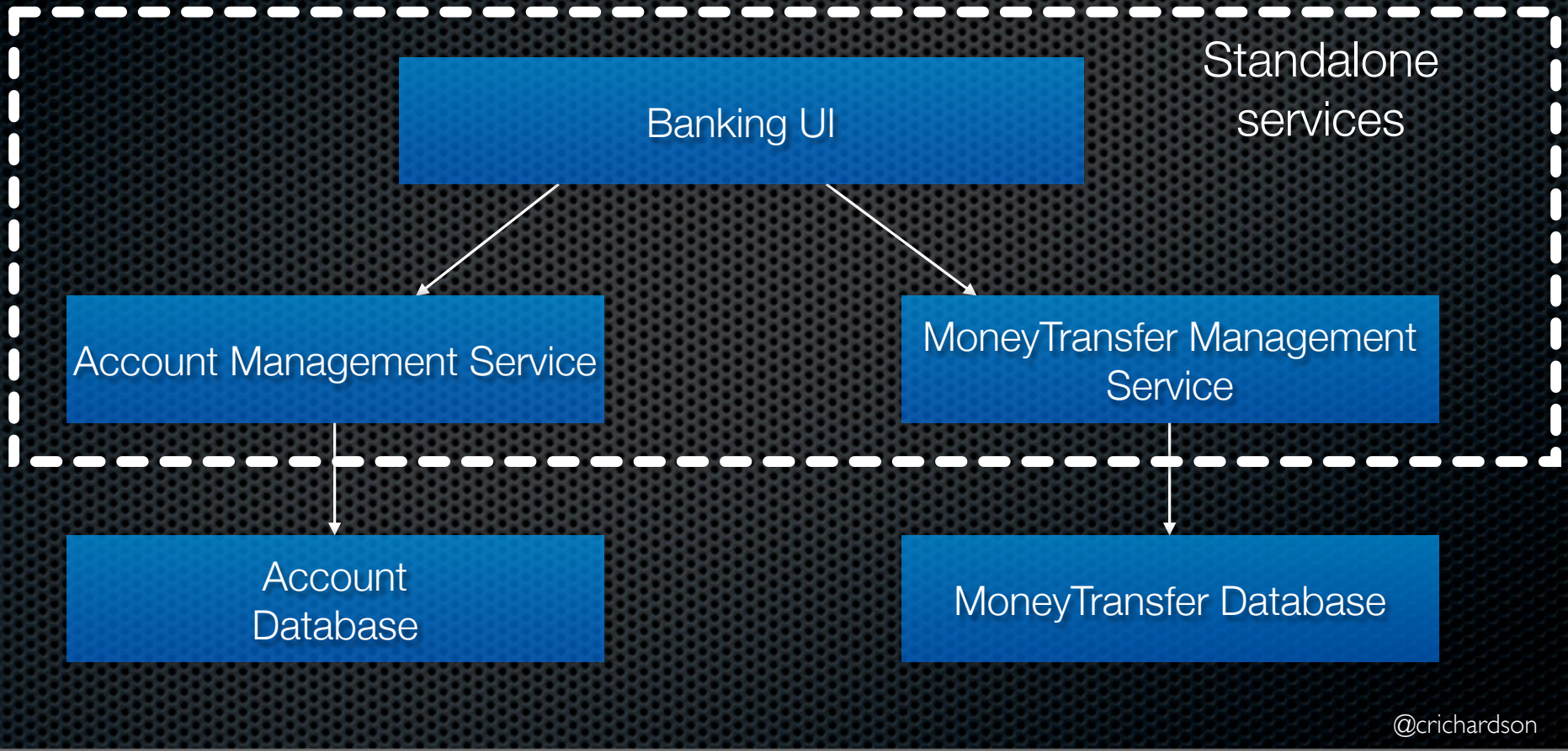
Simple to

develop
test
deploy
scale

Problem #1: monolithic architecture

- Intimidates developers
- Obstacle to frequent deployments
- Overloads your IDE and container
- Obstacle to scaling development
- Modules having conflicting scaling requirements
- Requires long-term commitment to a technology stack

Solution #1: use a microservice architecture



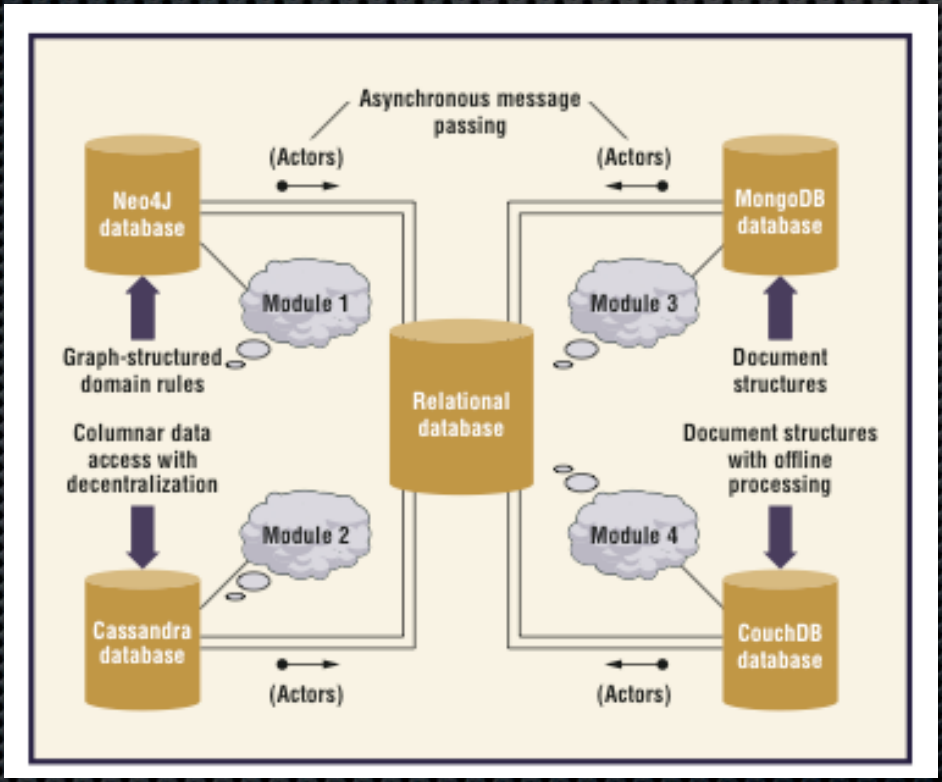
Problem #2: relational databases

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

Solution #2: use NoSQL databases

- Avoids the limitations of RDBMS
- For example,
  - text search ⇒ Solr/Cloud Search
  - social (graph) data ⇒ Neo4J
  - highly distributed/available database ⇒ Cassandra
  - ...

Different modules use different databases



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

But now we have problems with data consistency!

Problem #3: Microservices = distributed data management

- Each microservice has it's own database
- Business transactions must update data owned by multiple services,
  - e.g. Update MoneyTransfer and from/to Accounts
- Some data is replicated and must be kept in sync
- Tricky to implement reliably without 2PC

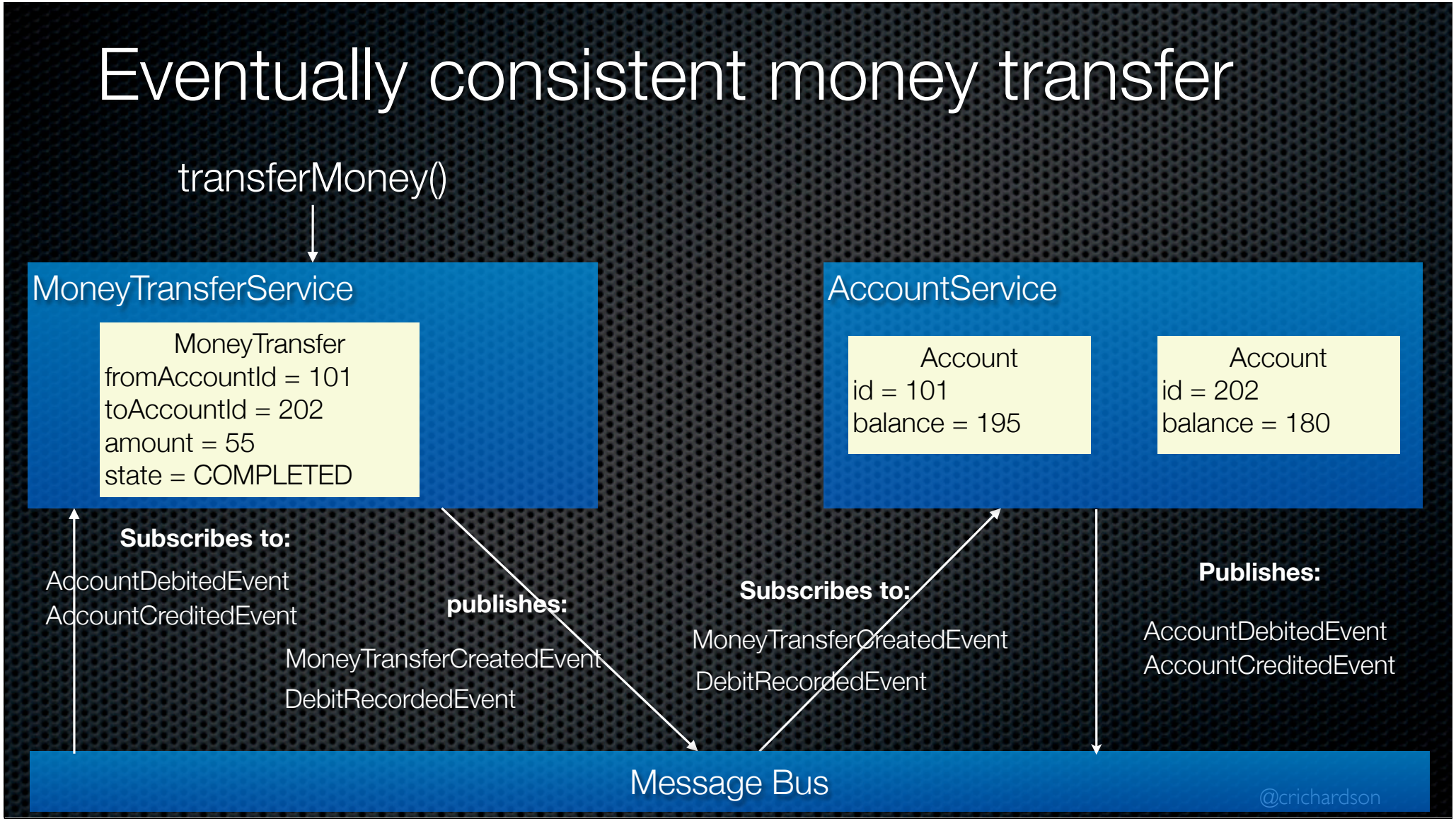
Problem #4: NoSQL = ACID-free, denormalized databases

- Limited transactions, i.e. no ACID transactions
  - Tricky to implement business transactions that update multiple rows,
  - e.g. Update MoneyTransfer and from/to Accounts
  - e.g. http://bit.ly/mongo2pc
- Limited querying capabilities
  - Requires denormalized/materialized views that must be synchronized
  - Multiple datastores (e.g. DynamoDB + Cloud Search) that need to be kept in sync

Solution to #3/#4: Event-based architecture to the rescue

- Microservices publish events when state changes
- Microservices subscribe to events
  - Maintains eventual consistency across multiple aggregates (in multiple datastores)
  - Synchronize replicated data

Eventually consistent money transfer



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

How to reliably generate events whenever state changes?

- Database triggers, Hibernate event listener, ...
  - Reliable BUT
  - Not with NoSQL
  - Disconnected from the business level event
  - Limited applicability
- Ad hoc event publishing code mixed into business logic
  - Publishes business level events BUT
  - Tangled code, poor separation of concerns
  - Unreliable, e.g. too easy to forget to publish an event

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

- Use 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 datastore as a message queue
  1. Update database: new entity state & event
  2. Consume event & mark event as consumed
  - Eventually consistent mechanism
  - 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 :-(

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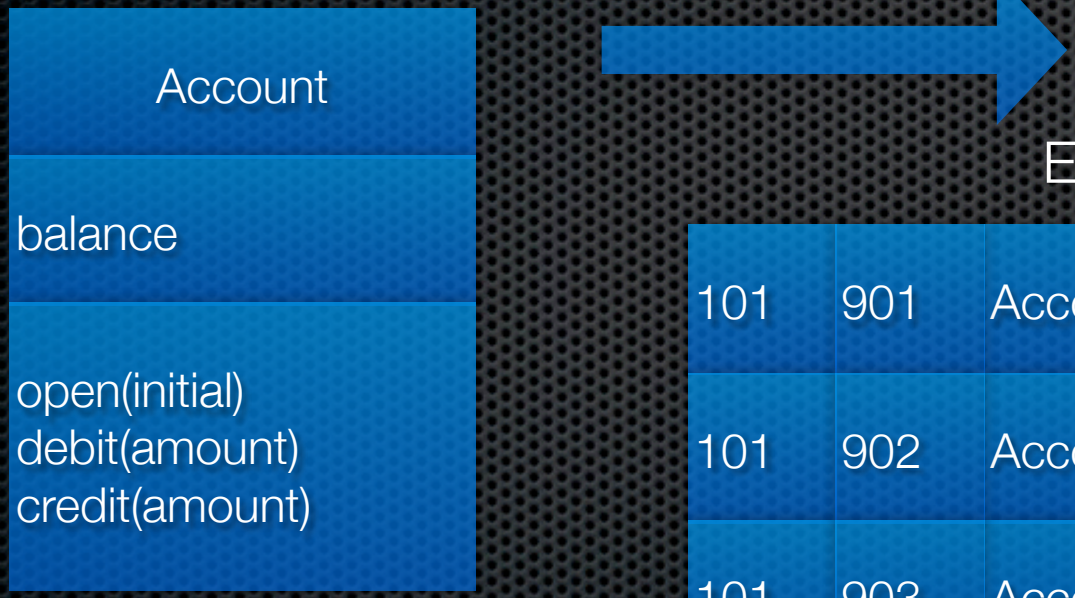
Event sourcing

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

Persists events NOT current state



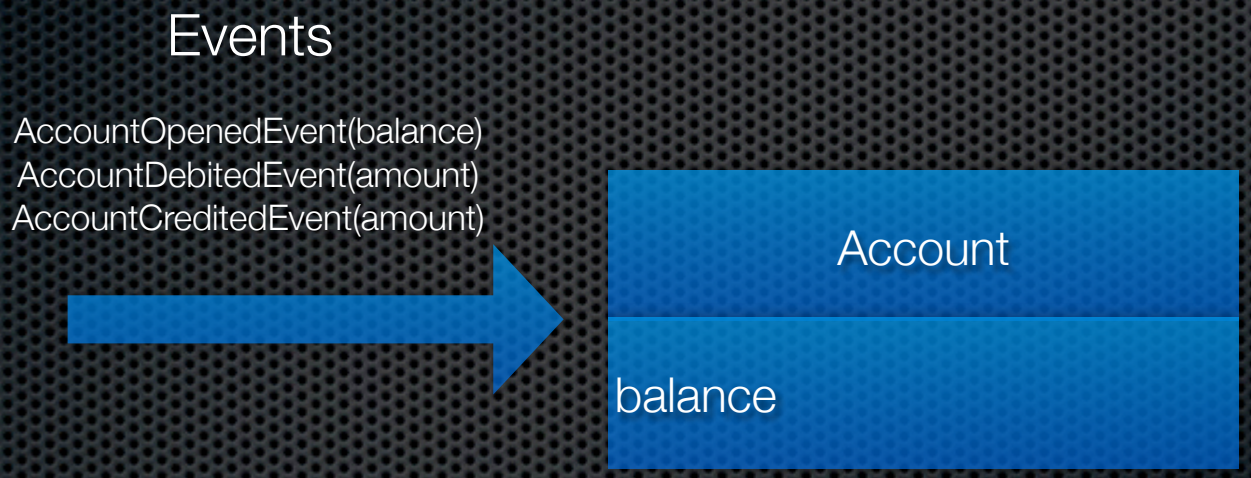
Account table

101	450

Event table

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

Replay events to recreate state



Two actions that must be atomic

Before: update state + publish events

Now: persist (and publish) events

Single action that can be done atomically

Aggregate traits

Apply event returning updated Aggregate

```
trait Aggregate[T] { self : T =>
  def applyEvent : PartialFunction[Event, T]
}

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

Map Command to Events

Account - command processing

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

  def this() = this(null)

  import net.chrisrichardson.eventstore.examples.bank.accounts.AccountCommands._

  def processCommand = {
    case OpenedAccountCommand(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))
  }
```

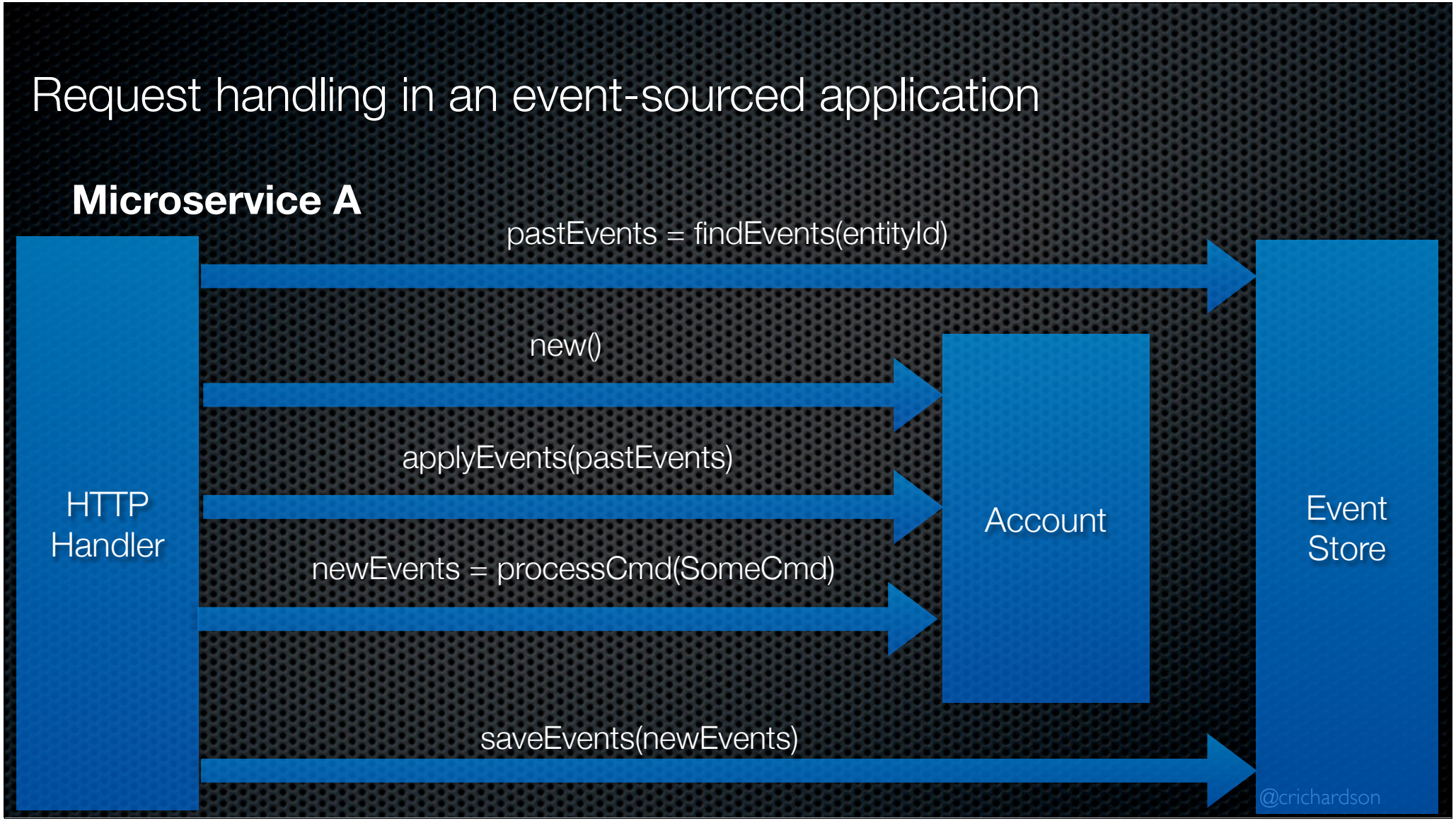
Prevent overdraft

Account - applying events

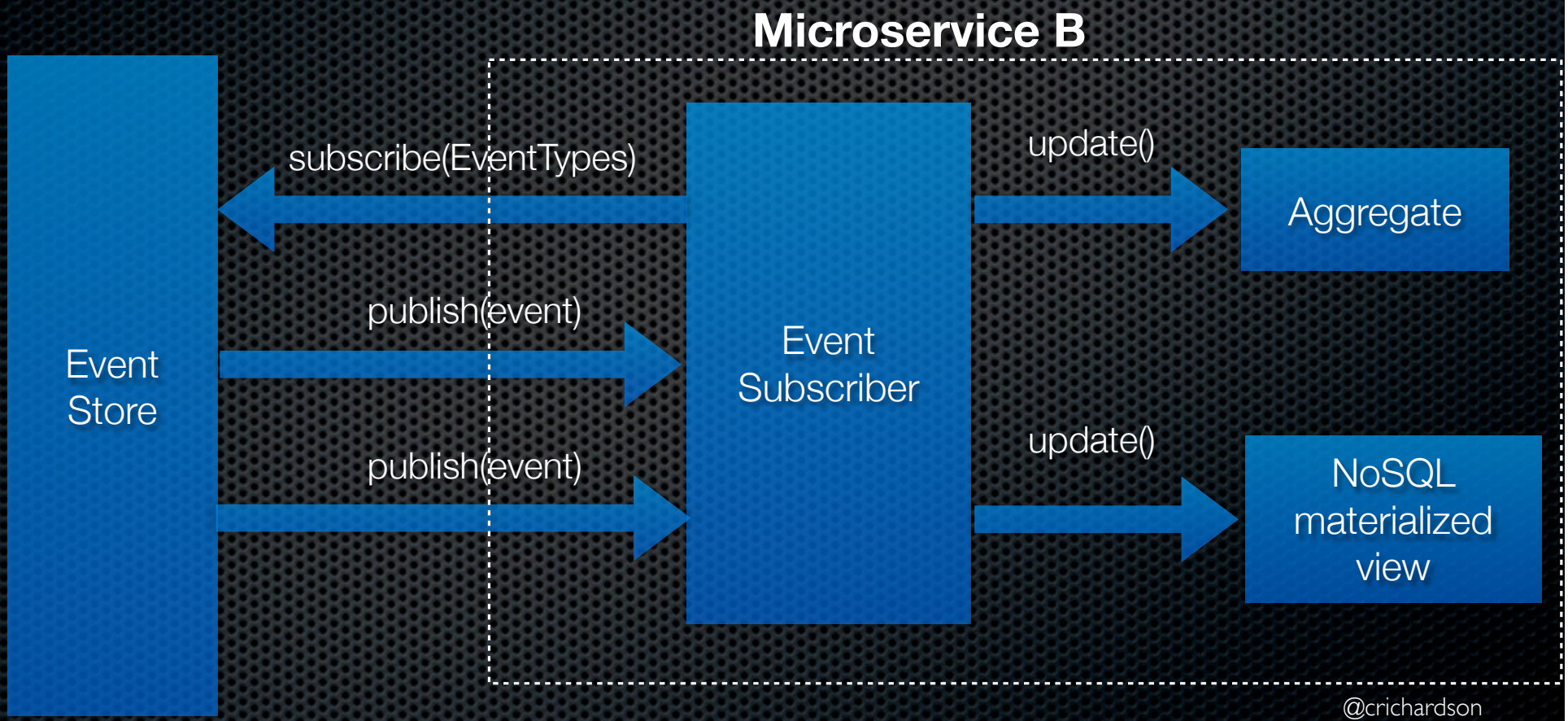
Immutable

```
case class Account(balance : BigDecimal)
  extends CommandProcessingAggregate[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

  }
```

Request handling in an event-sourced application



Event Store publishes events - consumed by other services



Persisting events

- Ideally use a cross platform format
- Use weak serialization:
  - enables event evolution, eg. add memo field to transfer
  - missing field ⇒ provide default value
  - unknown field ⇒ ignore
- JSON is a good choice

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

Event Store API

```
trait EventStore {

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

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

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

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

  def subscribe(subscriptionId: SubscriptionId):
       Future[AcknowledgableEventStream]
}
```

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)

Example of an eventual consistency problem

- Scenario:
  1. Create the user
  2. Create shopping cart
  3. Update the user with the shopping cart's id
- The user temporarily does not have a shopping cart id!
  - Client might need to retry their request at a later point
  - Server should return status code 418??

Handling duplicate events

- Idempotent operations
  - e.g. add item to shopping cart
- Duplicate detection:
  - e.g. track most recently seen event and discard earlier ones

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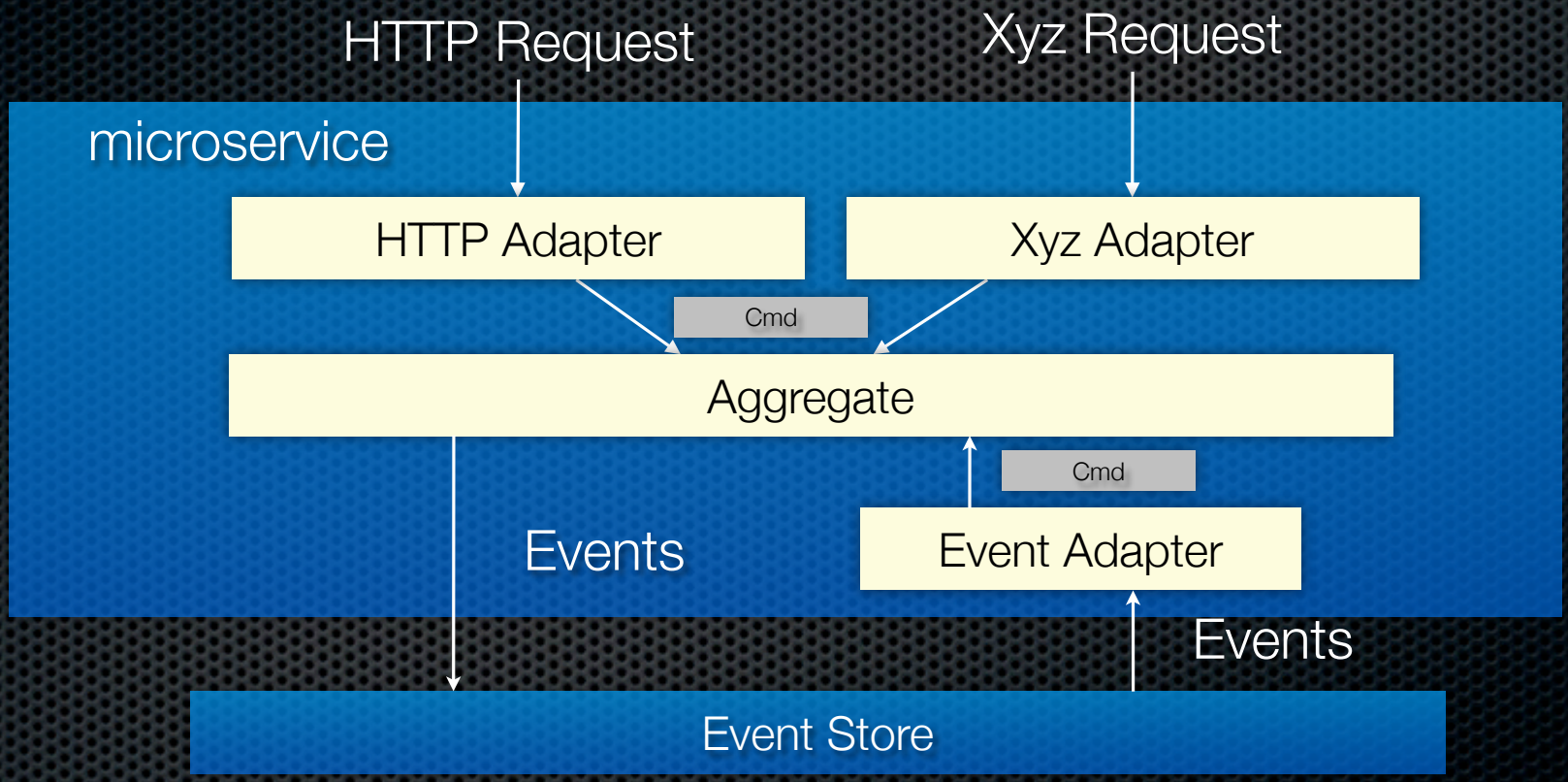
The anatomy of a microservice



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)
  }
```

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

MoneyTransfer Aggregate

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

case class MoneyTransfer(state : TransferStates.State, details : TransferDetails)
  extends CommandProcessingAggregate[MoneyTransfer, MoneyTransferCommand] {

  def this() = this(TransferStates.NEW, null)

  import net.chrisrichardson.eventstore.examples.bank.transactions.MoneyTransferCommands._

  def processCommand = {...}

  def applyEvent = {...}

}
```

```
case class MoneyTransferCreatedEvent(details : TransferDetails) extends Event
case class DebitRecordedEvent(details : TransferDetails) extends Event
case class CreditRecordedEvent(details : TransferDetails) extends Event
case class TransferFailedDueToInsufficientFundsEvent() extends Event
```

Handling events published by Accounts

```
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

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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

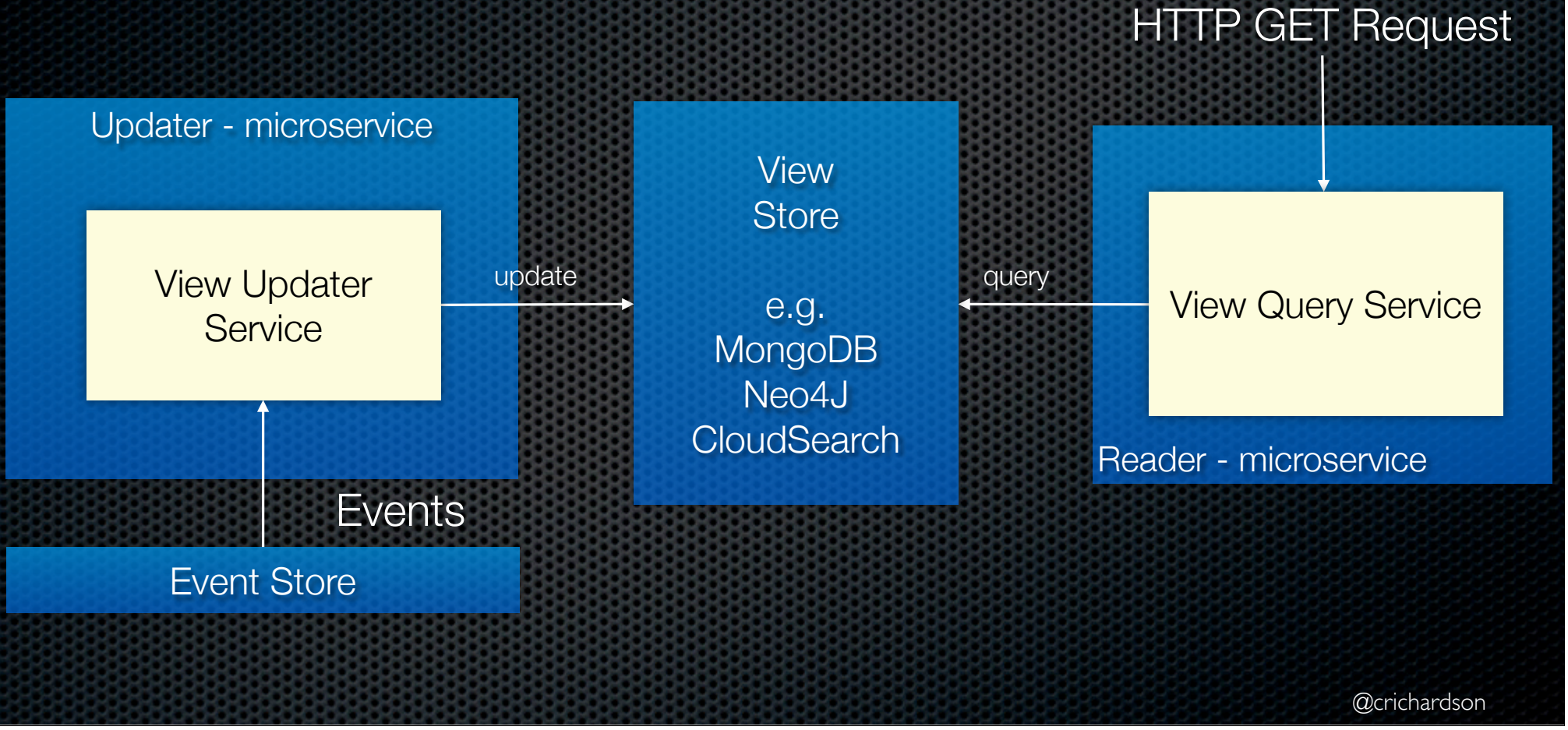
- Event Store = primary key lookup of individual aggregates, ...

⇒

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

Command Query Responsibility Separation (CQRS)

Query-side microservices



Persisting account balance and recent transactions in MongoDB

```
{
   id: "298993498",
   balance: 100000,
   transfers : [
      {"transferId" : "4552840948484",
       "fromAccountId" : 298993498,
       "toAccountId" : 3483948934,
       "amount" : 5000}, ...
   ],
   changes: [
     {"changeId" : "93843948934",
      "transferId" : "4552840948484",
      "transactionType" : "AccountDebited",
      "amount" : 5000}, ...
   ]
}
```

Current balance

Transfers that update the account

The sequence of debits and credits

Denormalized = efficient lookup

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

Dealing with eventually consistent views

- Scenario:
  - Client creates/updates aggregate
  - Client requests view of aggregate
- Problem:
  - The view might not yet have been updated
- Solution:
  - Create/Update response contains aggregate version
  - Query request contains desired version
  - Out of date view ⇒ wait or return “out of date view” error code
- Alternatively:
  - “Fake it” in the UI until the view is updated

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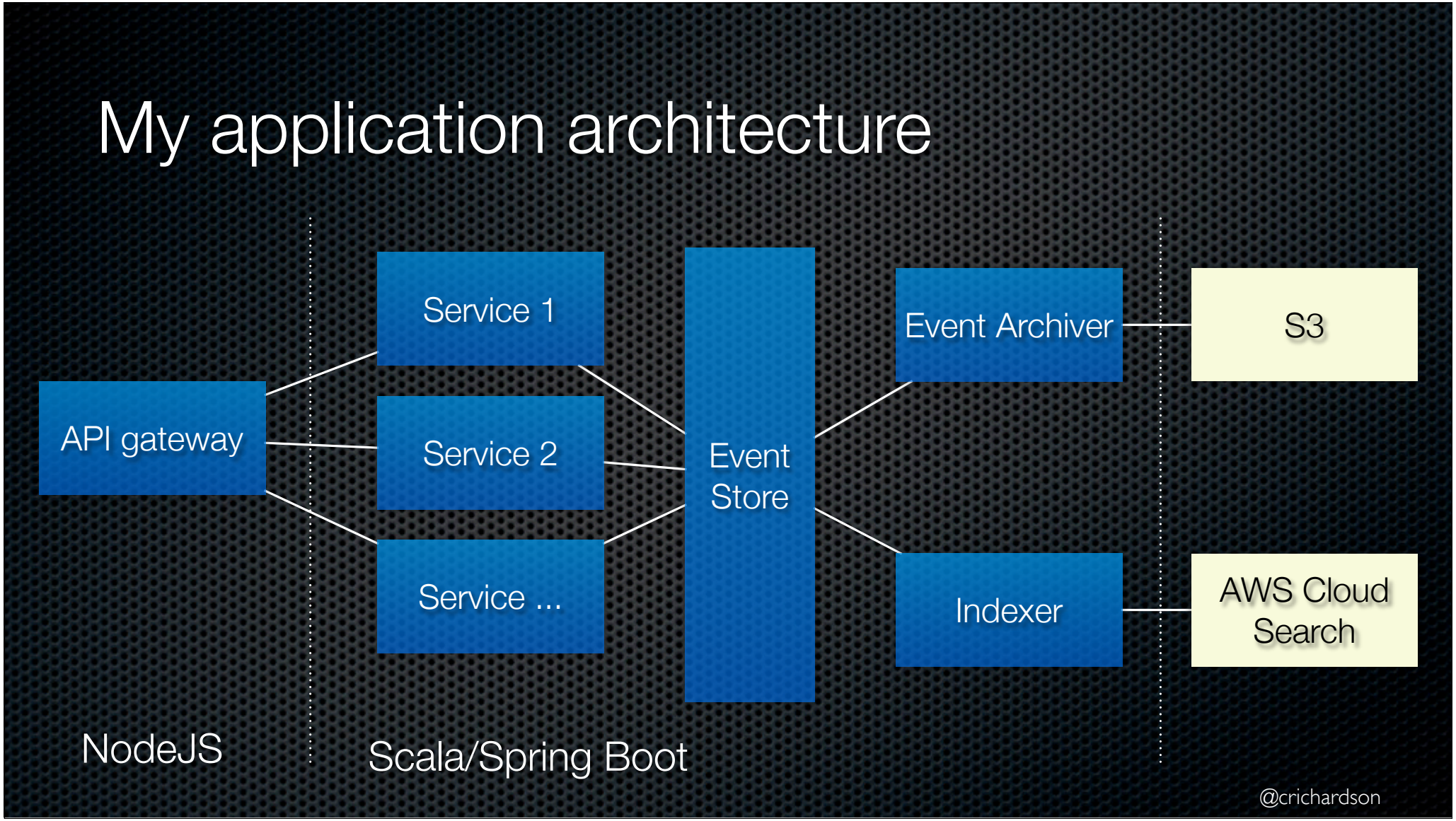
My application architecture



Jenkins-based deployment pipeline

One pipeline per microservice

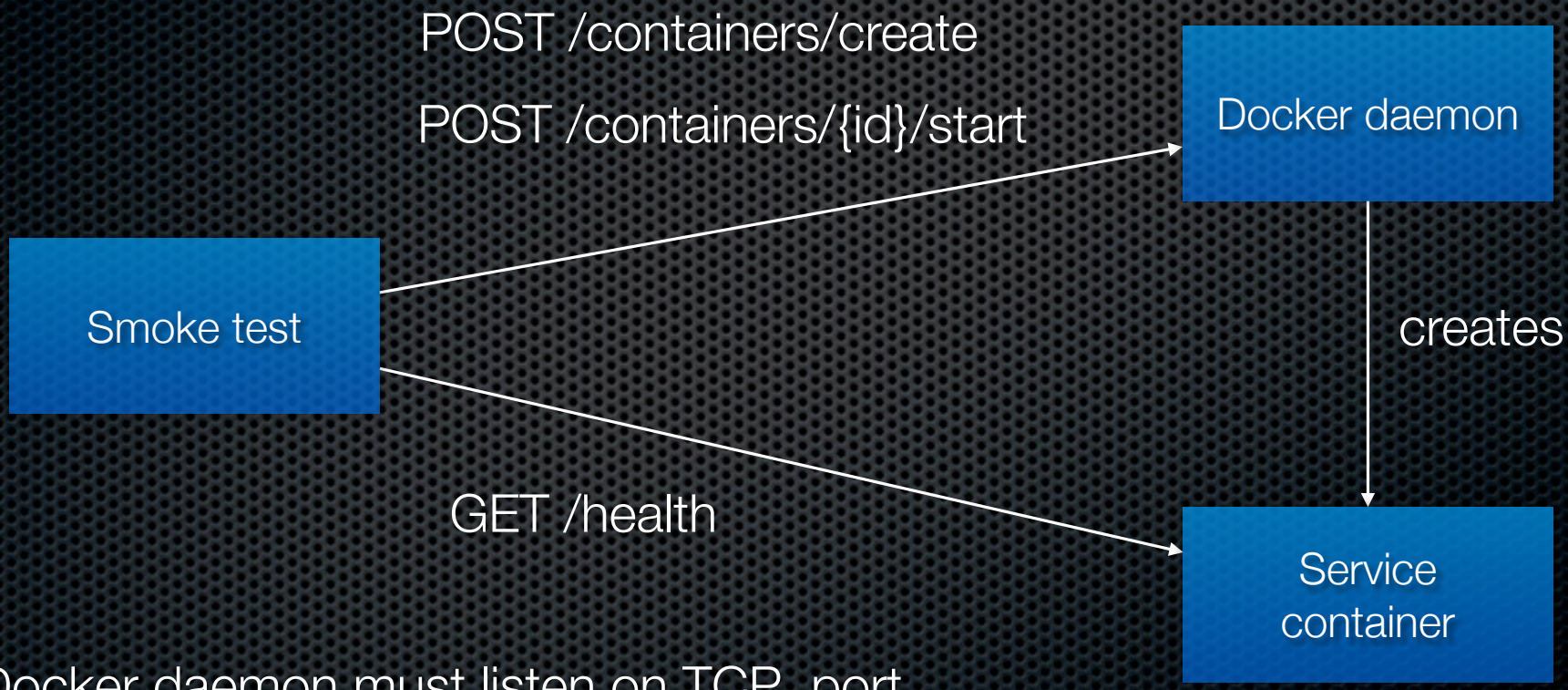
Building Docker images

docker/build.sh

```
cp ../build/libs/service.${1}.jar build/service.jar


docker build -t service-${VERSION} .
```

Smoke testing docker images



Docker daemon must listen on TCP port

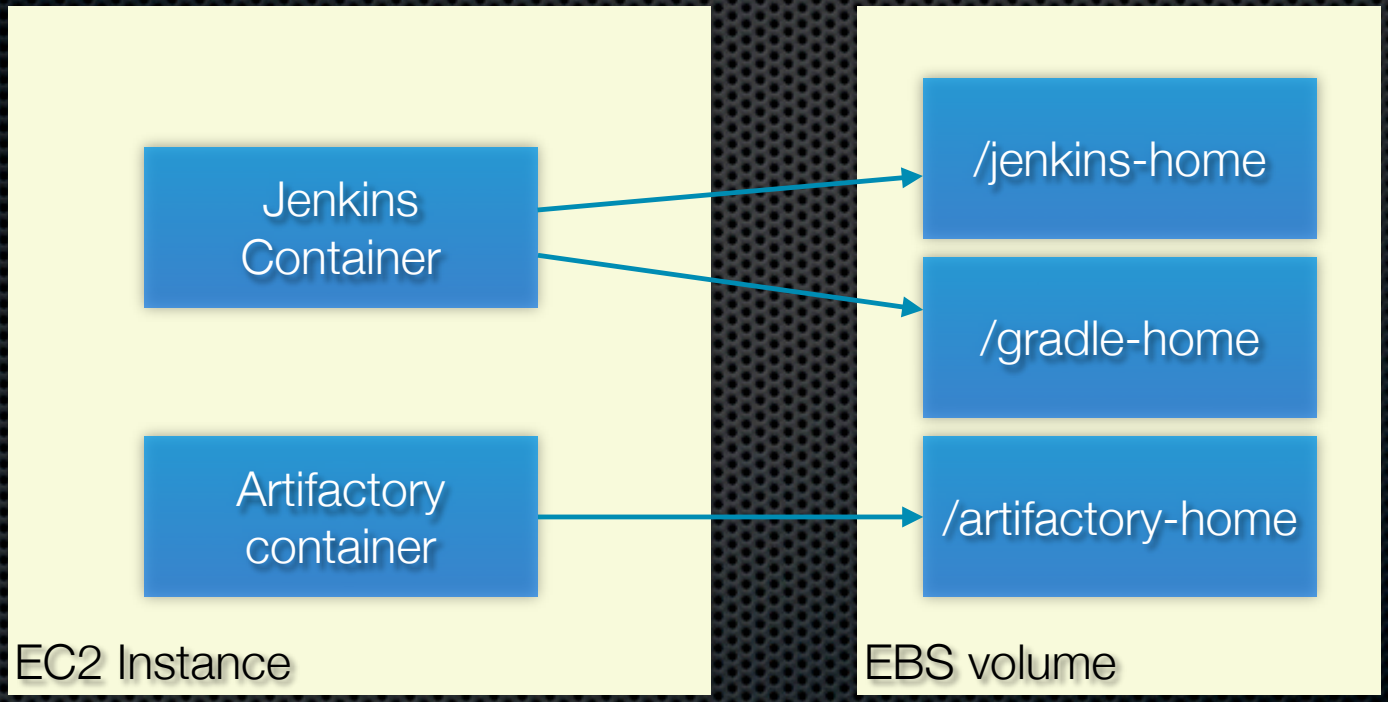
Publishing Docker images

docker/publish.sh

```
docker tag service-${VERSION}:latest \
    ${REGISTRY_HOST_AND_PORT}/service-${VERSION}


docker push ${REGISTRY_HOST_AND_PORT}/service-${VERSION}
```

CI environment runs on Docker



Updating production environment

- Large EC2 instance running Docker
- Deployment tool:
  1. Compares running containers with what's been built by Jenkins
  2. Pulls latest images from Docker registry
  3. Stops old versions
  4. Launches new versions
- One day: use Docker clustering solution and a service discovery mechanism,
  - Mesos and Marathon + Zookeeper, Kubernetes or ???

Summary

- Event sourcing solves key data consistency issues with:
  - Microservices
  - Partitioned SQL/NoSQL databases
- Use CQRS to implement materialized views for queries
- Docker is a great way to package microservices


@crichardson chris@chrisrichardson.net
Questions? Let's talk at the Open Space
http://plainoldobjects.com
http://microservices.io