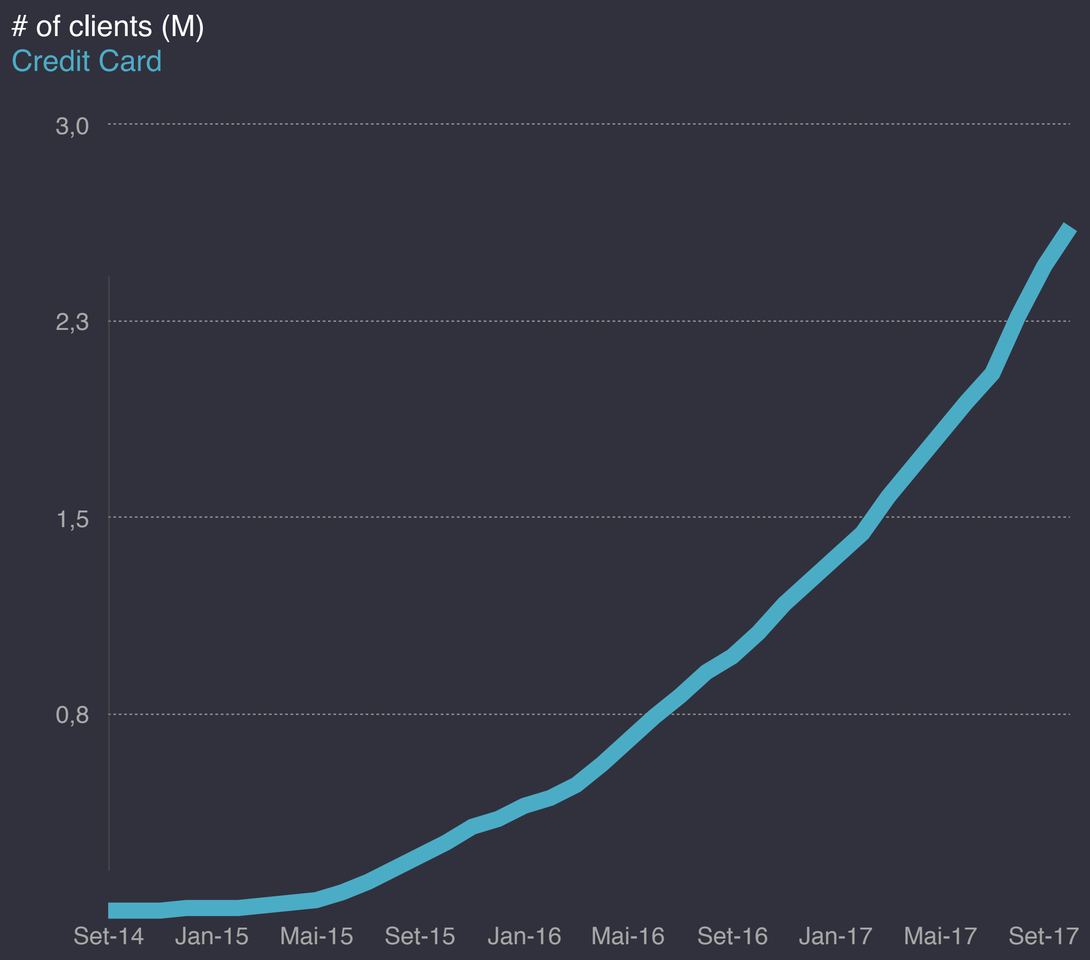
Architecting a Modern Financial Institution

SOUTHEAST BRAZIL REGION FROM SPACE

CREDIT CARD

September 2014

GROWING QUICKLY IN A COMPLEX DOMAIN



10.5M
Unique applications

20
Deploys per day

2.6M
Customers

120
Microservices

262M
Purchases

105
Engineers

198
Countries

IMMUTABLE THEMES FROM OUR STACK

CLOJURE

DATOMIC

KAFKA

CLOUD

LISP hosted on the JVM

Functional (opinionated), immutable data structures

Simple, concise, fast, concurrent

Tight REPL feedback cycles

Gradual typing (schemas)

IMMUTABLE THEMES FROM OUR STACK

CLOJURE

DATOMIC

KAFKA

CLOUD

for your data

Accumulate-only

Reified ACID transactions, preserve what changed when

Query using data structures (Datalog)

Cloud native with integrated caching and scalable reads

IMMUTABLE THEMES FROM OUR STACK

CLOJURE

DATOMIC

KAFKA

CLOUD

Immutable, persistent, partitioned log

Logical decoupling between services

Temporal decoupling, useful for asymmetric workloads

Fault isolation and recovery (circuit breakers, dead letters)

Financial batch jobs expressed as a streams of messages

IMMUTABLE THEMES FROM OUR STACK

CLOJURE

DATOMIC

KAFKA

CLOUD

Infra as code (AWS)

Immutable upon provisioning (Docker)

Blue-Green deploys at service and company level

Kubernetes for speed and scalability

Nubank HQ
São Paulo, Brazil

FUNCTIONAL BENEFITS

HIRING

POSITIVE SELF SELECTION
1-MONTH RAMP

COMPLEXITY

SMALL, PURE FUNCTIONS
STRAIGHTFORWARD TO UNTANGLE

CONSISTENCY

COMPOSING A SMALL NUMBER OF IDIOMATIC LANGUAGE FEATURES

CREDIT CARD ARCHITECTURE

Greenfield MVP

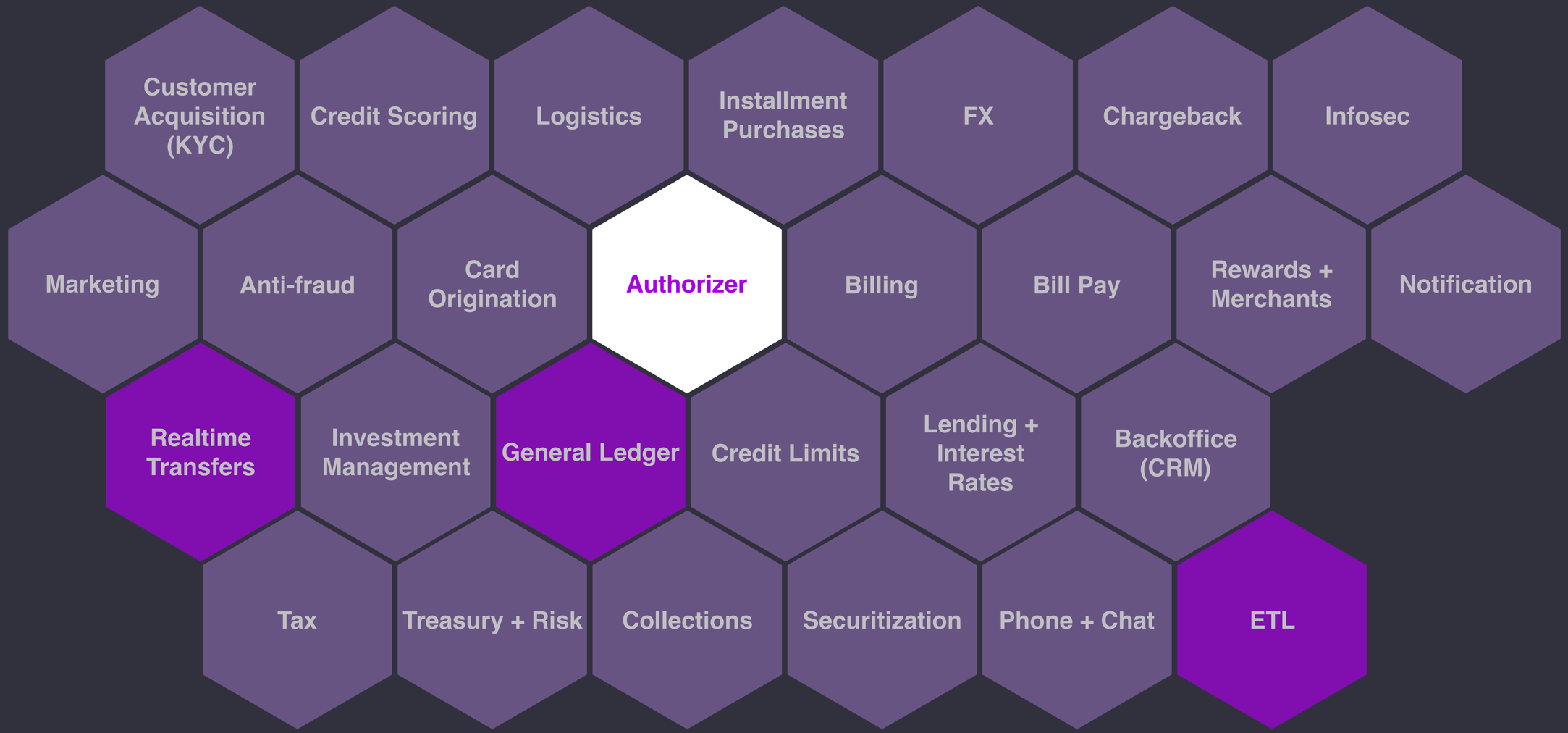
BANK ACCOUNT

October 2017

CORE BANKING + CREDIT CARD ARCHITECTURE

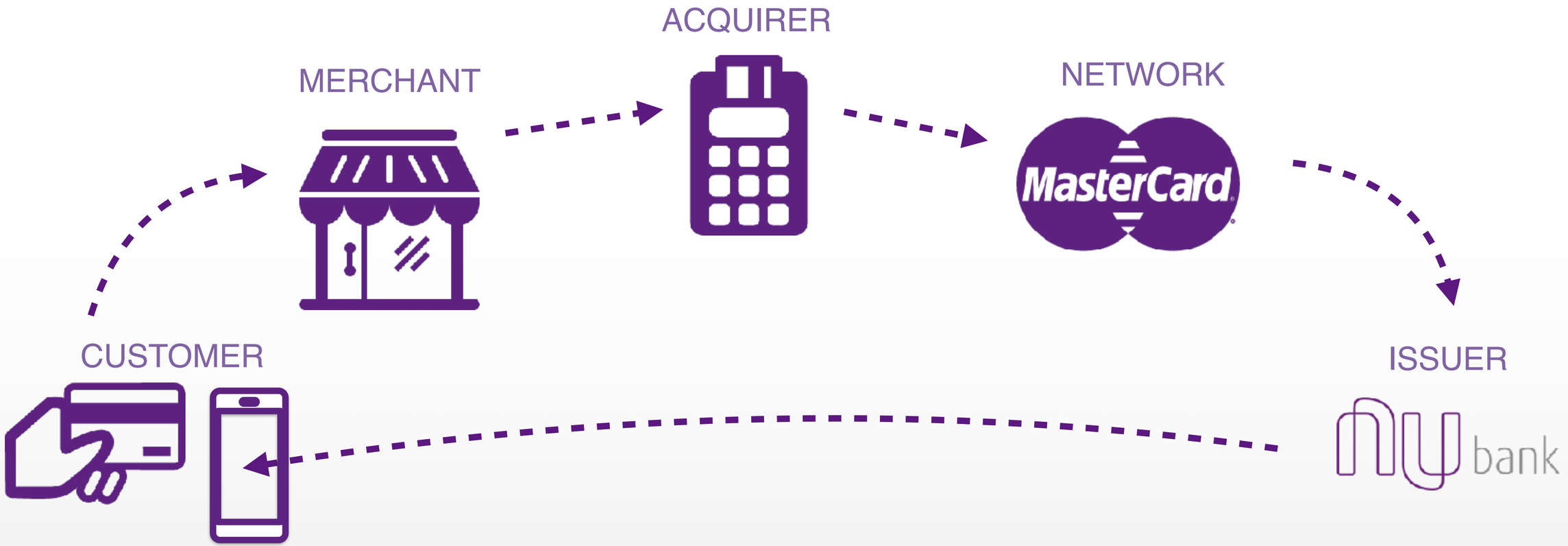
INFRASTRUCTURE

PURCHASE AUTHORIZATION



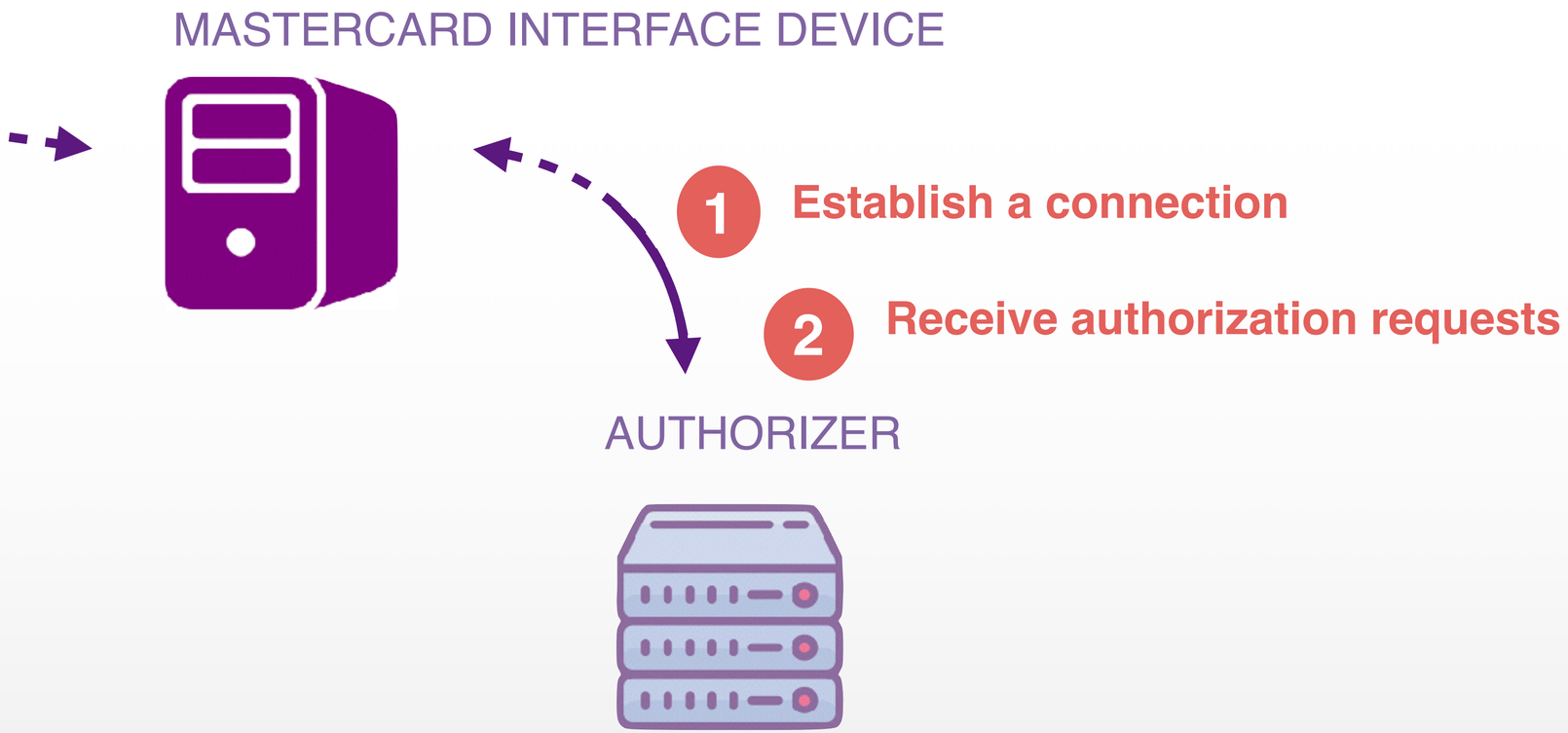
INFRASTRUCTURE

PURCHASE AUTHORIZATION VALUE CHAIN

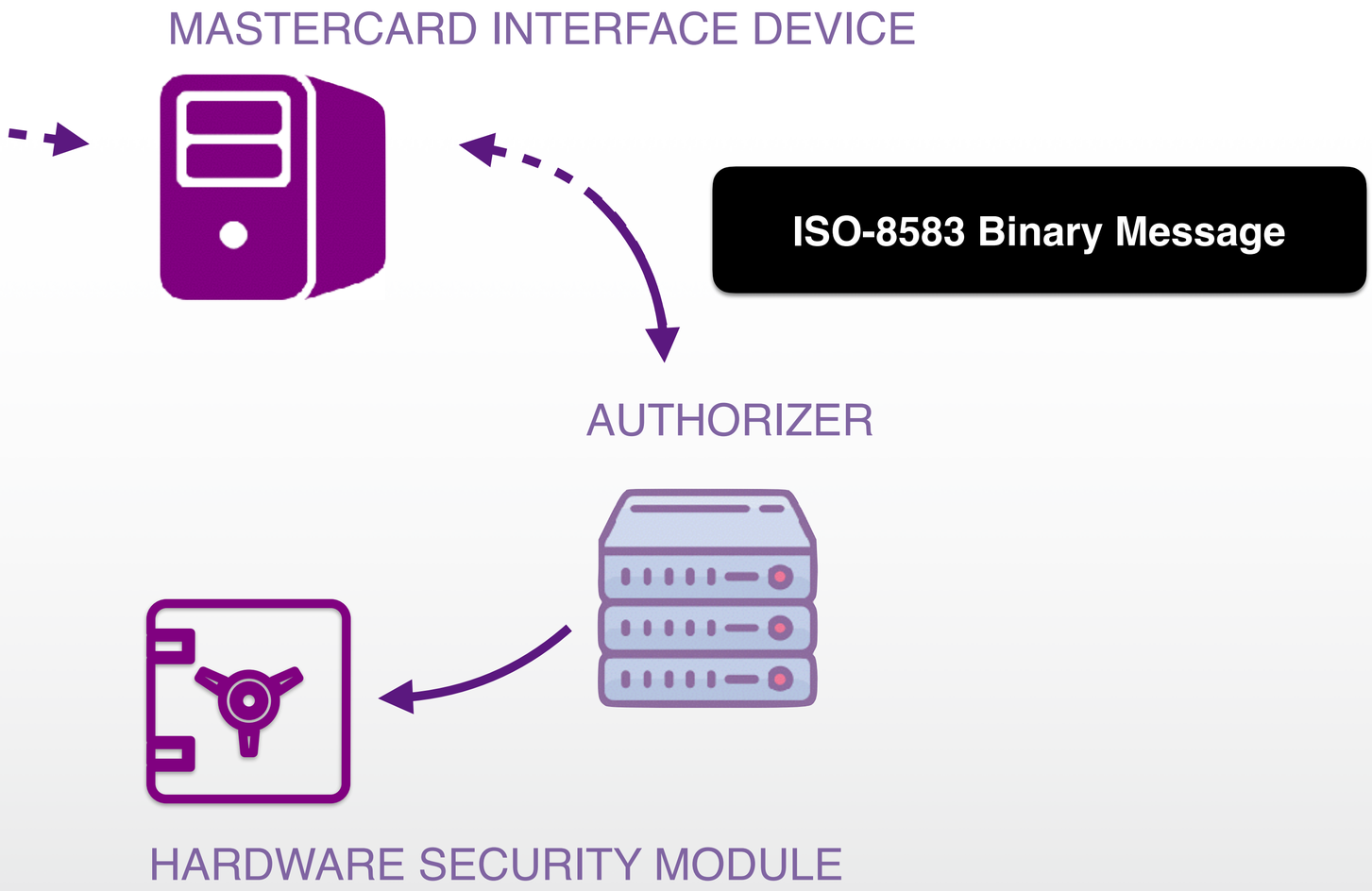


ISSUER AUTHORIZATION

ISSUER AUTHORIZATION



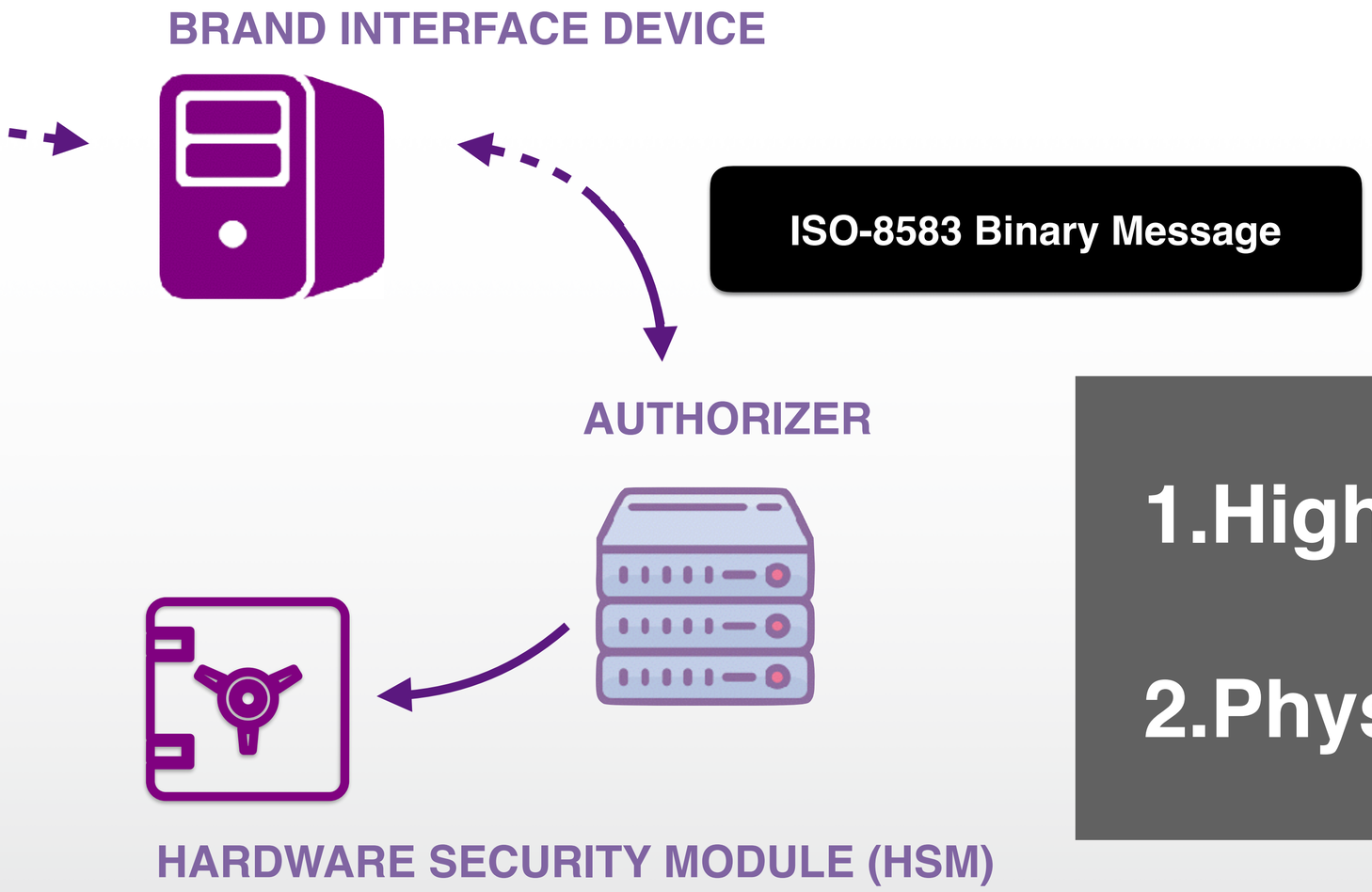
ISSUER AUTHORIZATION: ISO-8583



SCODEC BINARY PARSER FOR ISO-8583

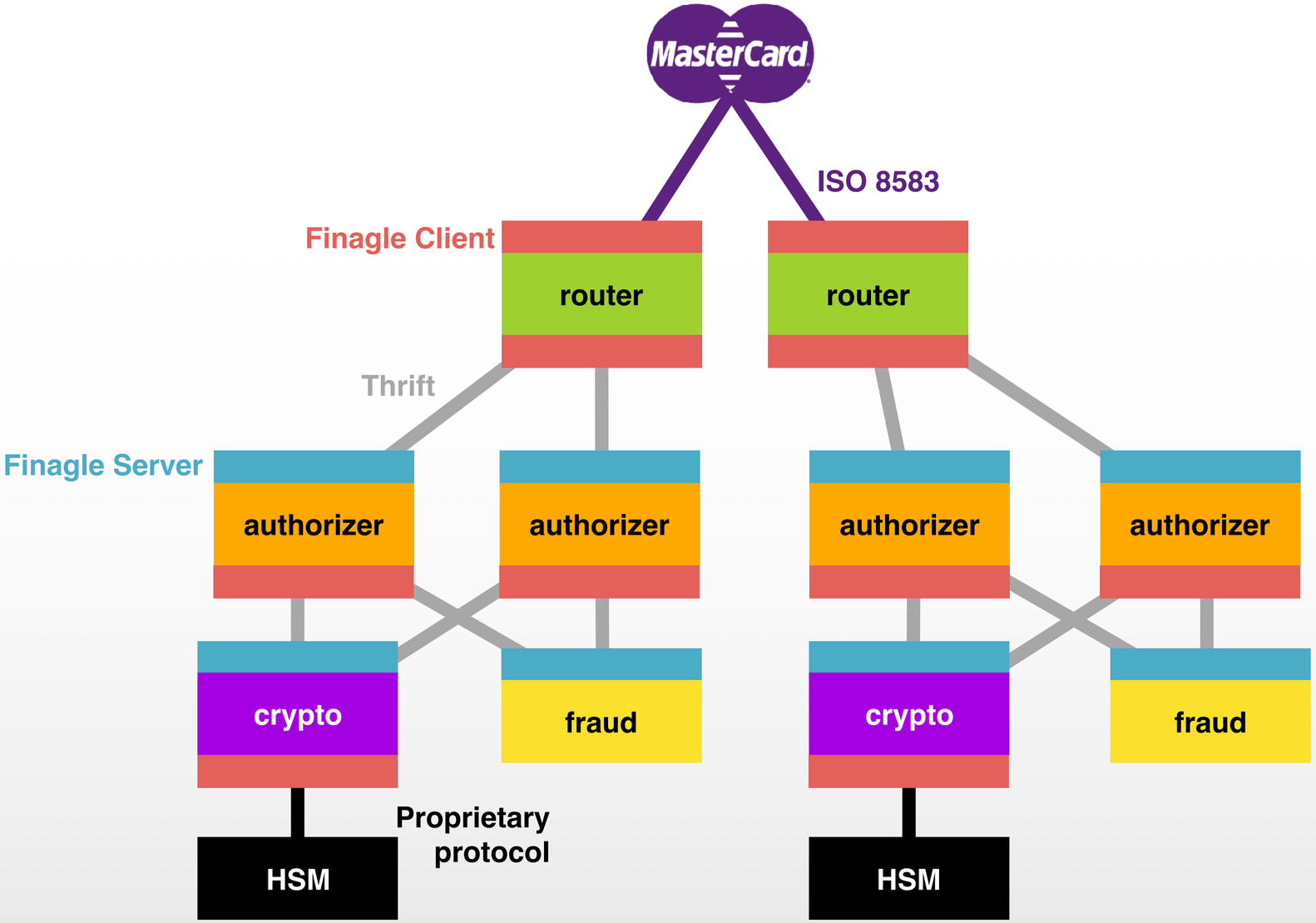
```
object PANMappingFileD {
    import scala.language.reflectiveCalls

    val codec: Codec[SE33Subfield] = discriminated[SE33Subfield].by(intPadded(2))
      .typecase(1, llvar(str).as[AccountNumberIndicator])
      .typecase(2, llvar(intString(intPadded(2))).as[AccountNumber])
      .typecase(3, llvar(yearMonth).as[ExpirationDate])
      .typecase(4, llvar(str).as[ProductCode])
      .typecase(5, llvar(intPadded(2)).as[TokenAssuranceLevel])
      .typecase(6, llvar(intString(intPadded(2))).as[TokenRequestorID])
      .typecase(7, llvar(intString(intPadded(2))).as[PANAccountRange])

}
```

ISSUER AUTHORIZATION: REQUIREMENTS



1. Highly Available
2. Physical Infrastructure

AUTHORIZER SERVICE LAYOUT



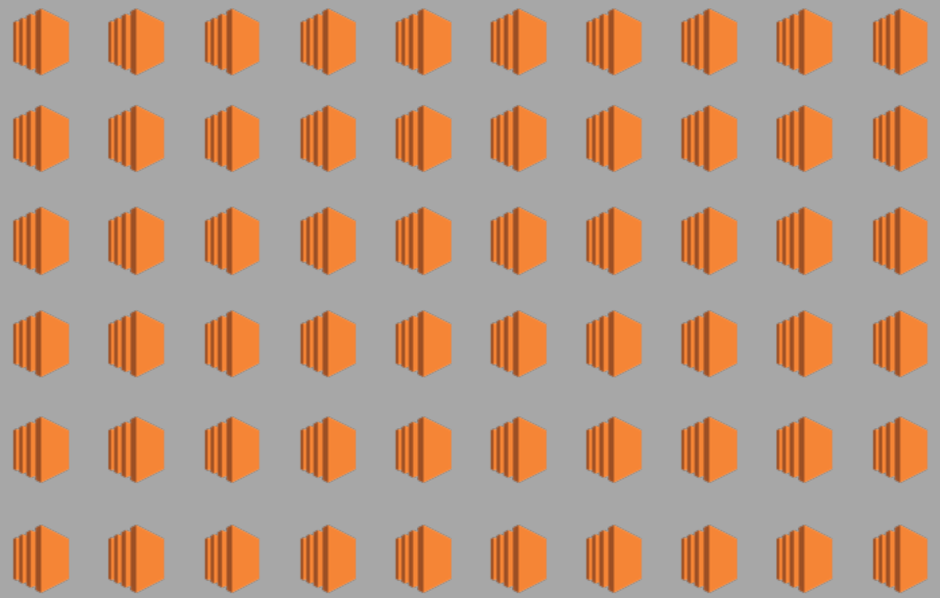
- Small set of highly available services
- Co-located with the MasterCard devices in the same datacenters
- Isolated: transaction authorization hot path does not need communication with the cloud
- Active-active disaster recovery (not shown)

KAFKA AS THE BRIDGE BETWEEN ENVIRONMENTS

“neverland”
(nubank datacenter)

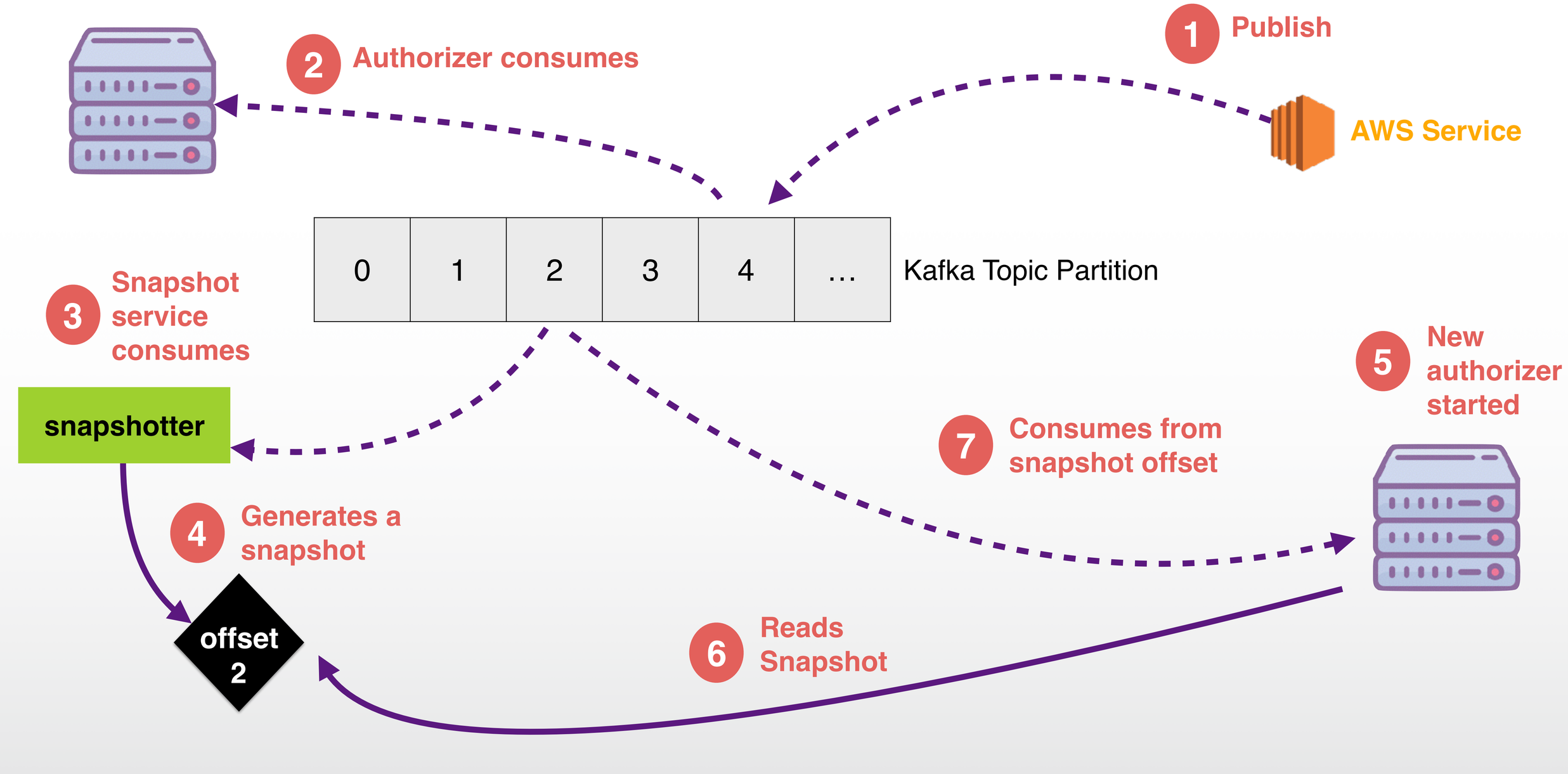
kafka

100+ microservices

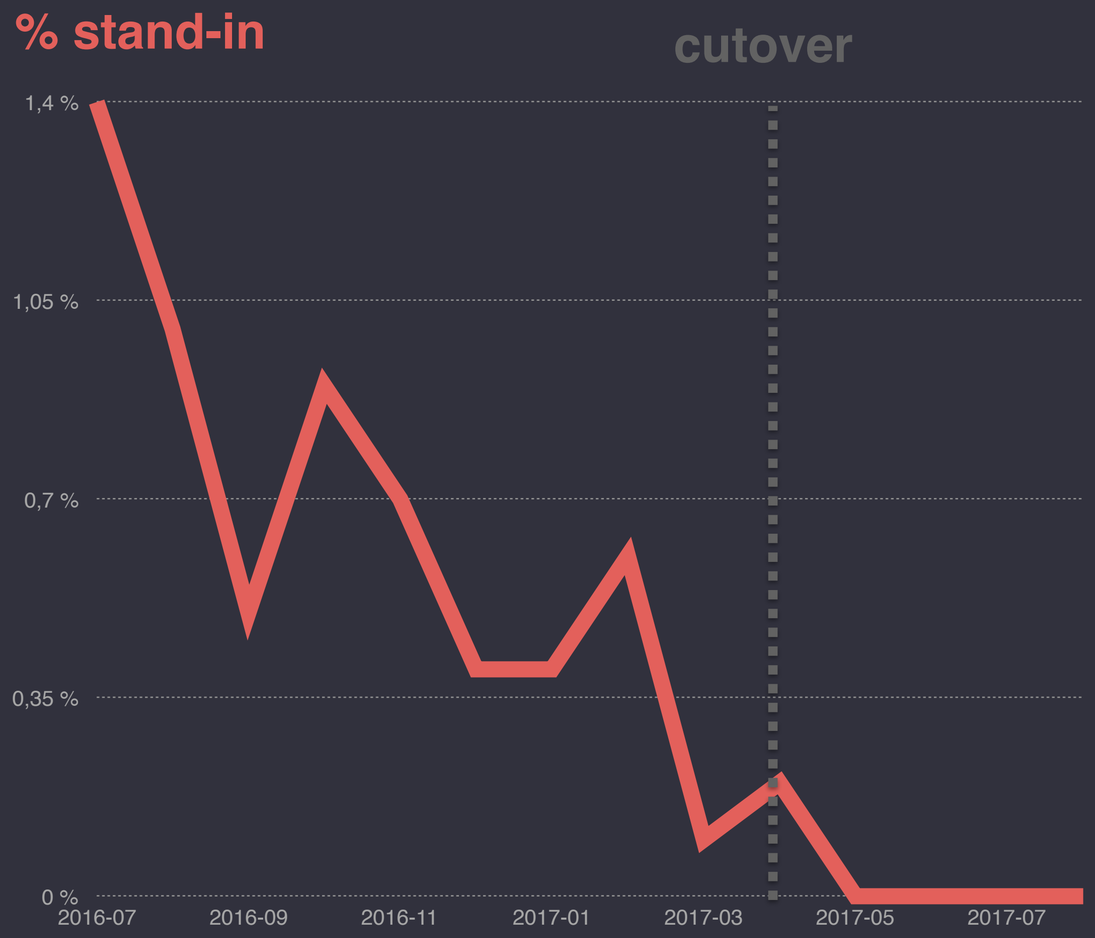


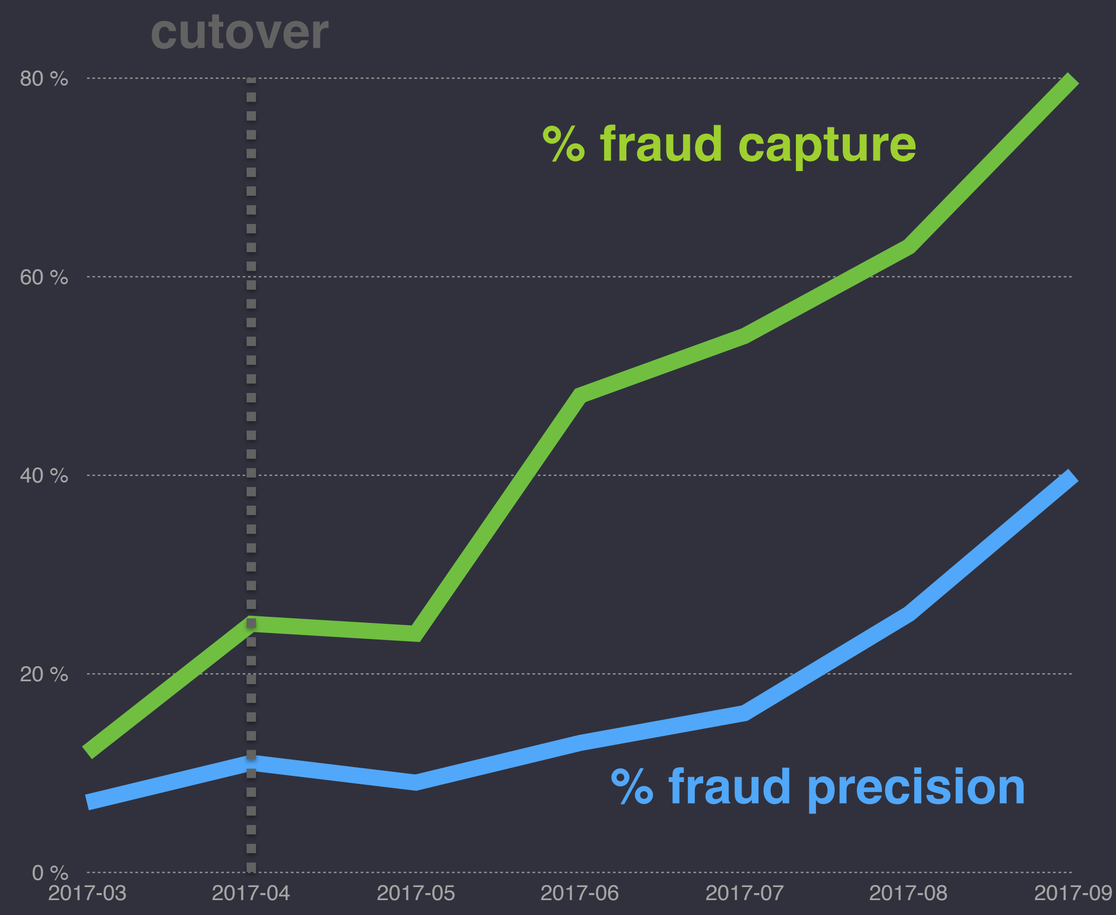
“the real world”
(AWS VPC)

KAFKA-BASED LOG/SNAPSHOT



DRAMATIC IMPROVEMENTS IN RELIABILITY AND FRAUD





DOUBLE ENTRY ACCOUNTING

INFRASTRUCTURE

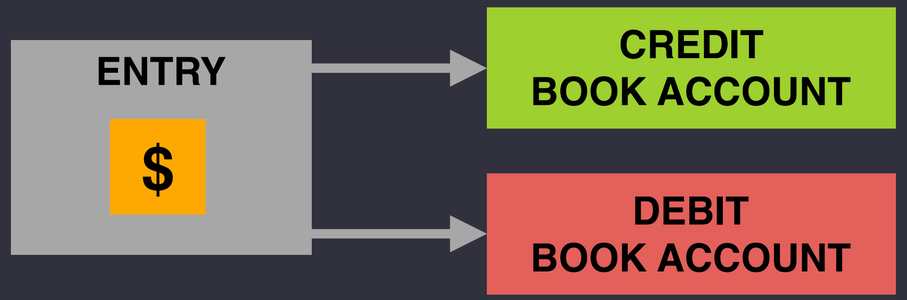
BUSINESS LOGIC DEPENDS ON DATA ACROSS MANY SERVICES

Should we…

authorize a purchase?
block a card?
charge interest?

Double Entry

DOUBLE ENTRY: THE MODEL



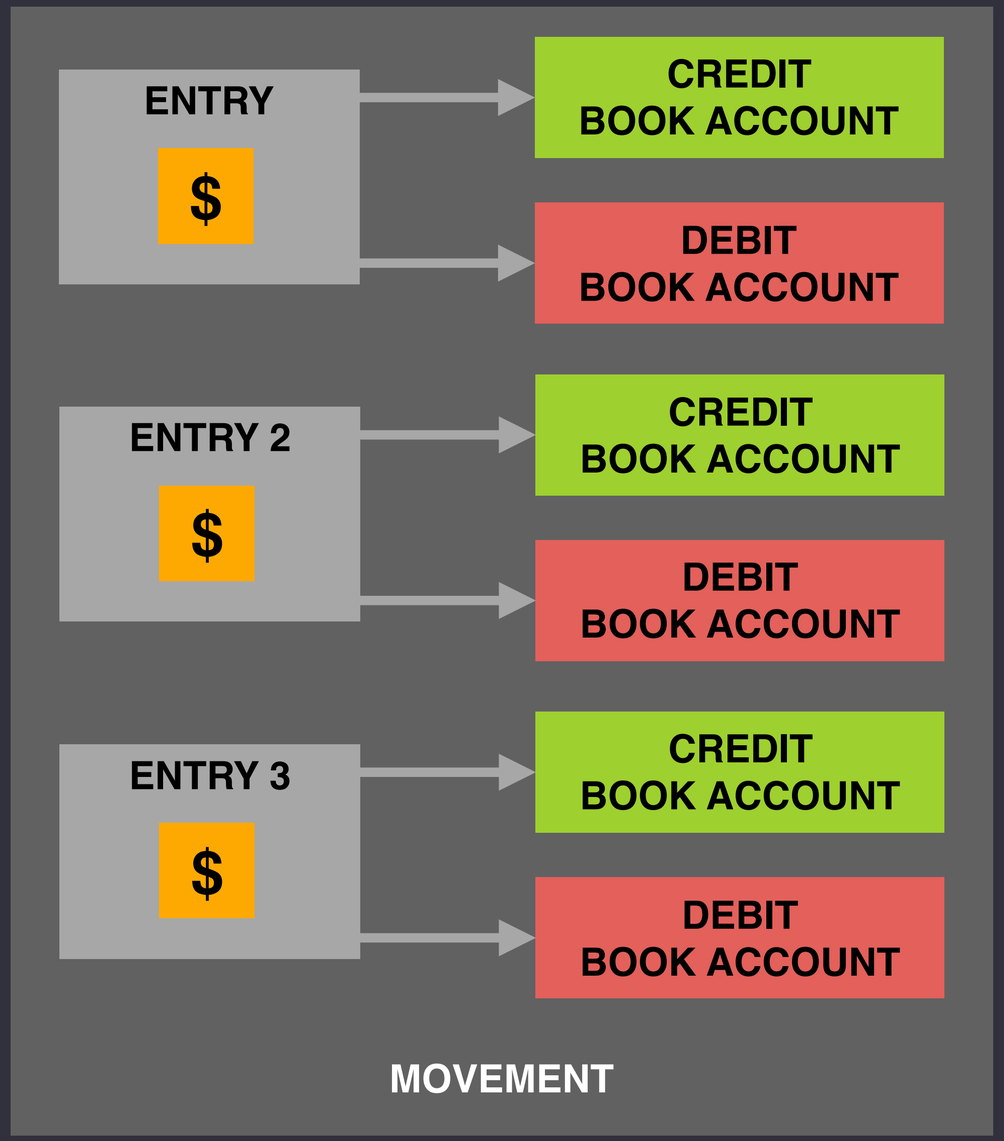
BALANCE $= \sum$ **$**

The sum of all credits and debits for one book-account is its balance

A customer’s balance sheet is a cumulative function of their entire history

DOUBLE ENTRY: THE RULEBOOK

NEW-PURCHASE
NEW-PAYMENT
…



DOUBLE ENTRY: EXAMPLE MOVEMENT

```
(def unsettled-purchase
  [

   {:entry/debit-account  :book-account-type.asset/unsettled
    :entry/credit-account :book-account-type.liability/unsettled-counterparty
    :entry/amount         #'transaction-amount
    :entry/post-date      #'produced-date}

   {:entry/debit-account  :book-account-type.liability/current-limit-counterparty
    :entry/credit-account :book-account-type.asset/current-limit
    :entry/amount         #'transaction-amount
    :entry/post-date      #’produced-date}

  ])
```

DOUBLE ENTRY: CHALLENGES

ordering matters (i.e. movements are not commutative)

late arriving events (e.g. *a payment was made 3 days ago*)

fixing invariants

write throughput

DOUBLE ENTRY: GENERATIVE TESTING OF INVARIANT

```
(def loss-property
  (prop/for-all [adjs (gen/vector (gen/one-of [gen-adjustment gen-payment gen-tx]) 1 10)
                 initial-state (gen/such-that (comp not #{:late :pre-loss} :state) rbh/initial-state-gen)
                 loss-event (gen/tuple (gen/no-shrink (gen/elements #{:pre-loss
                                                                      :credit-loss
                                                                      :id-fraud-loss
                                                                      :fraudster}))
                                       (tg/make-generator LocalDateTime)
                                       (tg/make-generator LocalDate))]
    (check-properties adjs initial-state loss-event)))
```

DOUBLE ENTRY: CHALLENGES

ordering actually matters (i.e. movements are not commutative)

late arriving events (e.g. *a payment was made 3 days ago*)

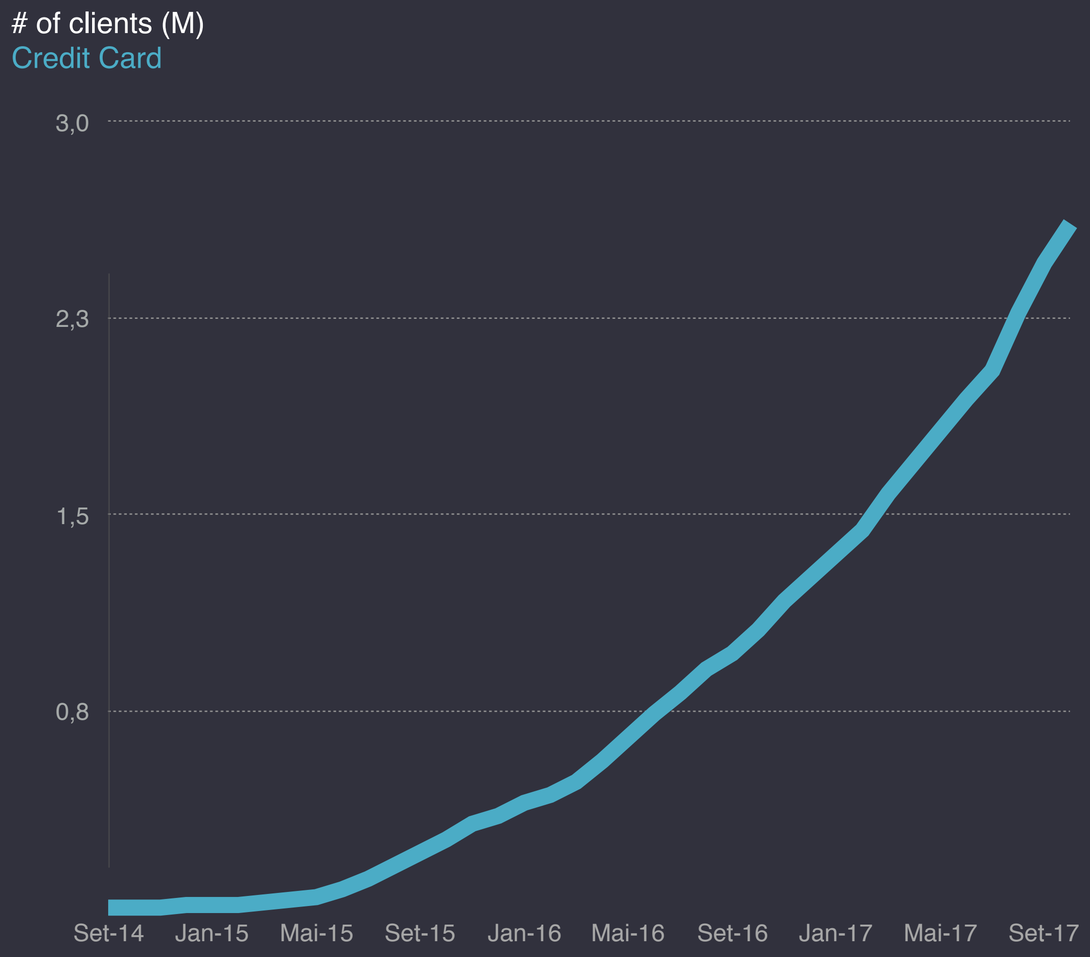
fixing invariants

write throughput

SHARDED, FAULT TOLERANT INFRASTRUCTURE

INFRASTRUCTURE

SCALING BOTTLENECKS



1. database throughput limits required throttling writes

2. batch job latency impacting customer experience

SCALING PLAN

Need to partition the workload

Customer data is spread across services

Interactions between customers are minimal

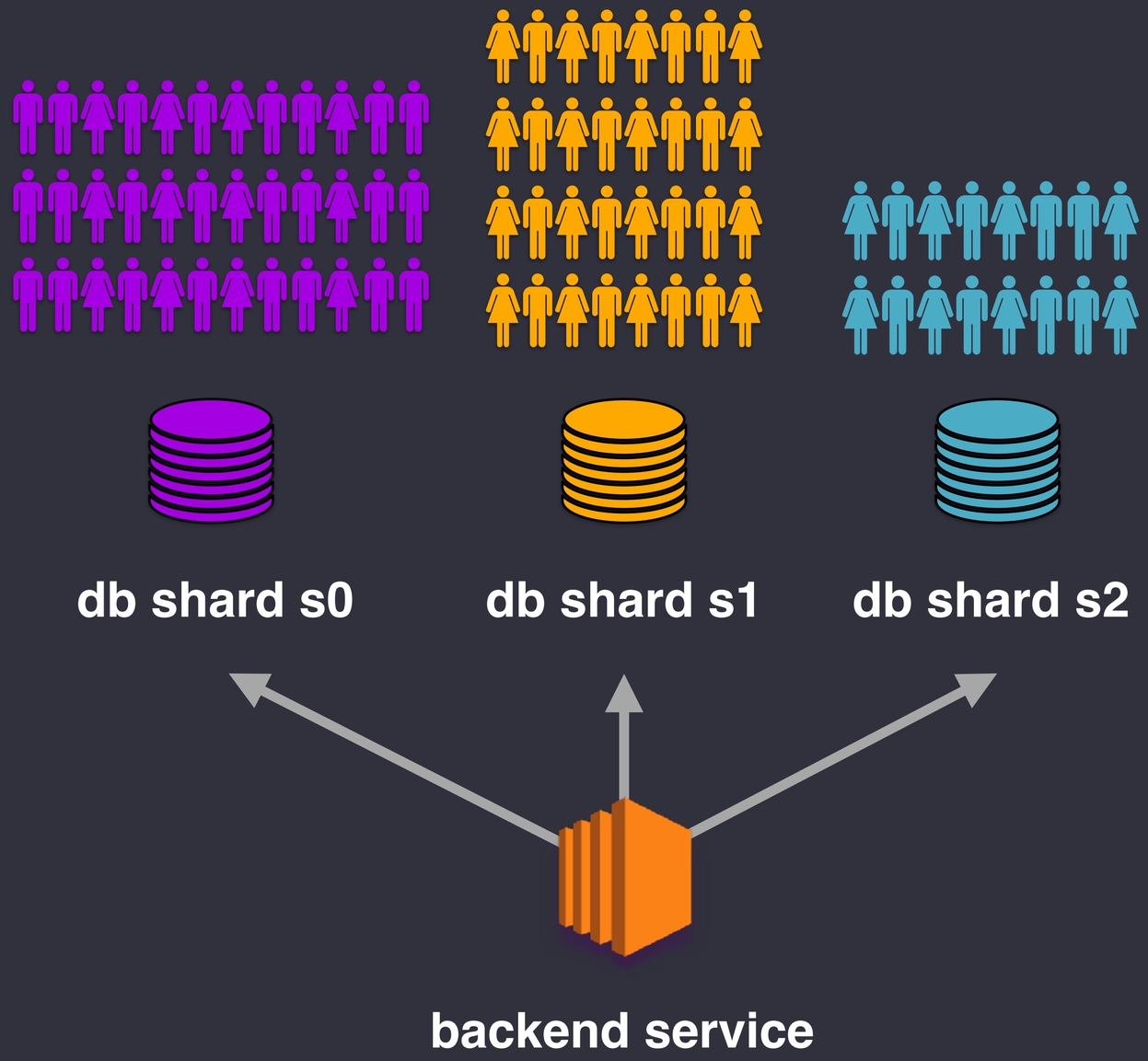
Safe to partition the user base

OPTION #1: PARTITION SERVICE DATABASES

Database writes were the worst bottleneck

Option: horizontally partition each database

Change every service to route queries and writes to the appropriate shard



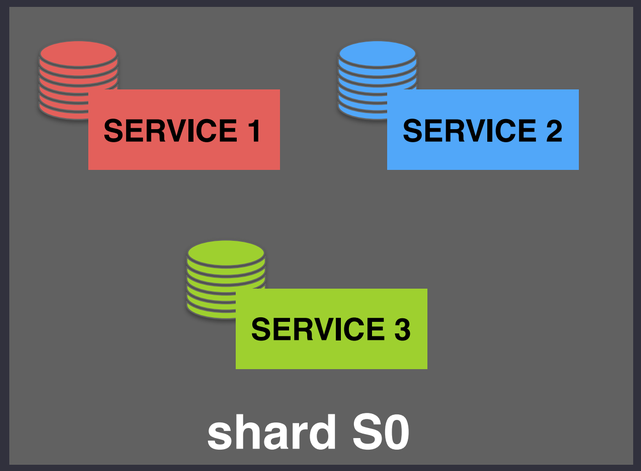
OPTION #1: PROBLEMS

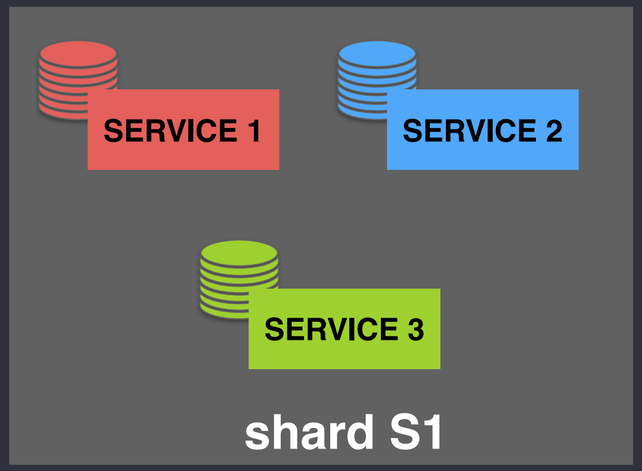
Enormous effort to change **every** service

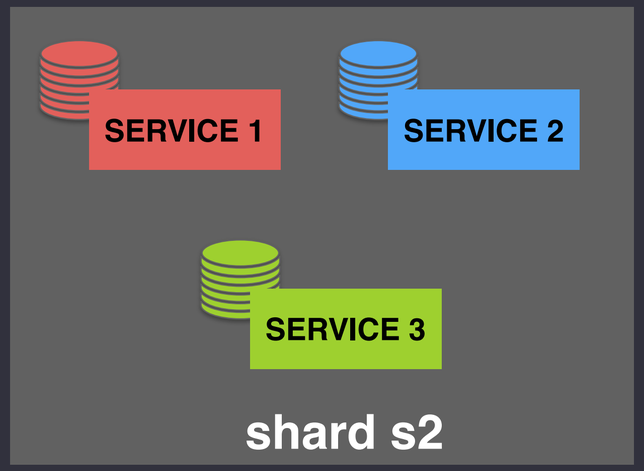
Doesn’t address **non-db** bottlenecks

Risks intermingling data infrastructure code with business logic

OPTION #2: SCALABILITY UNITS

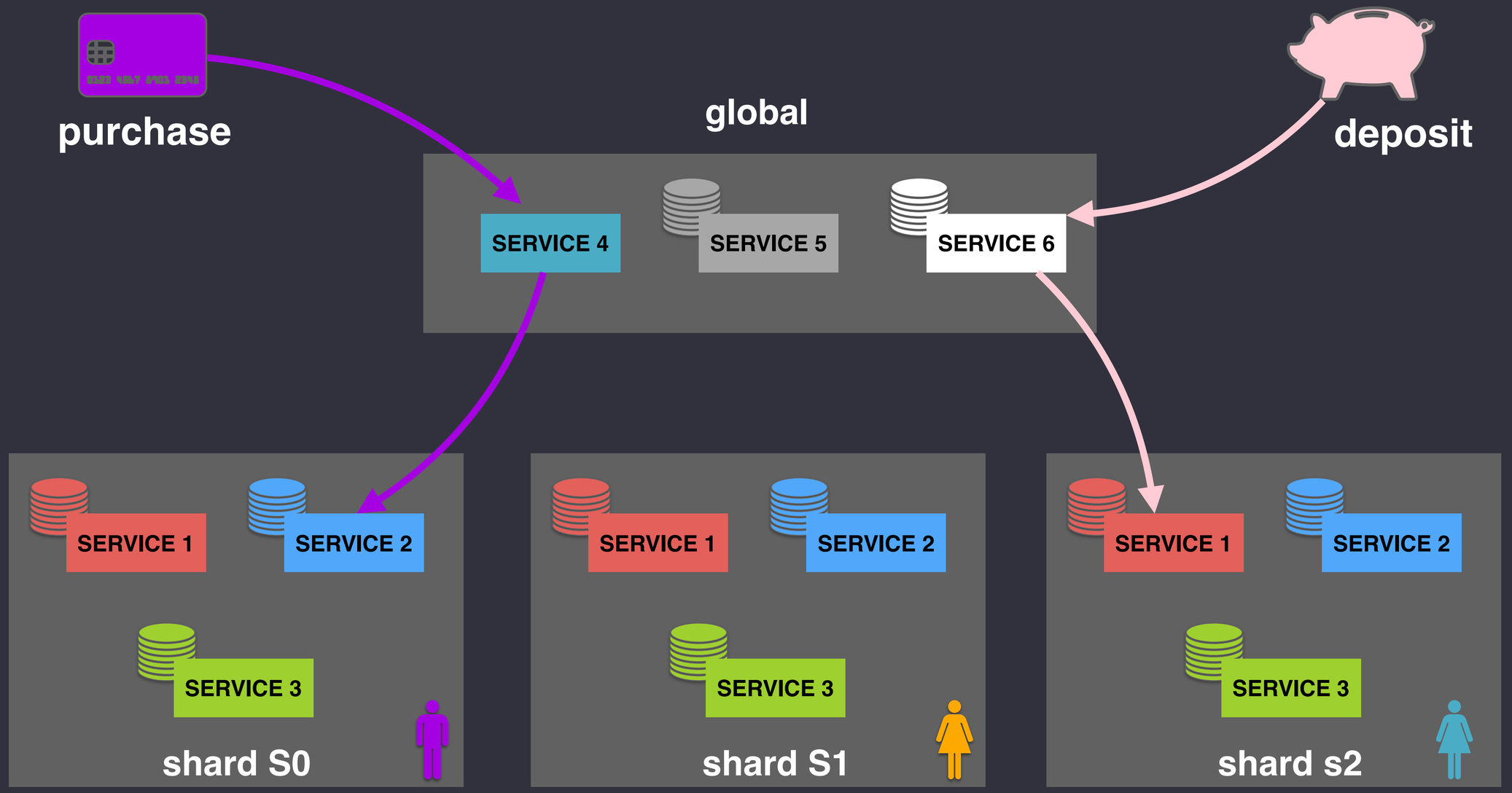




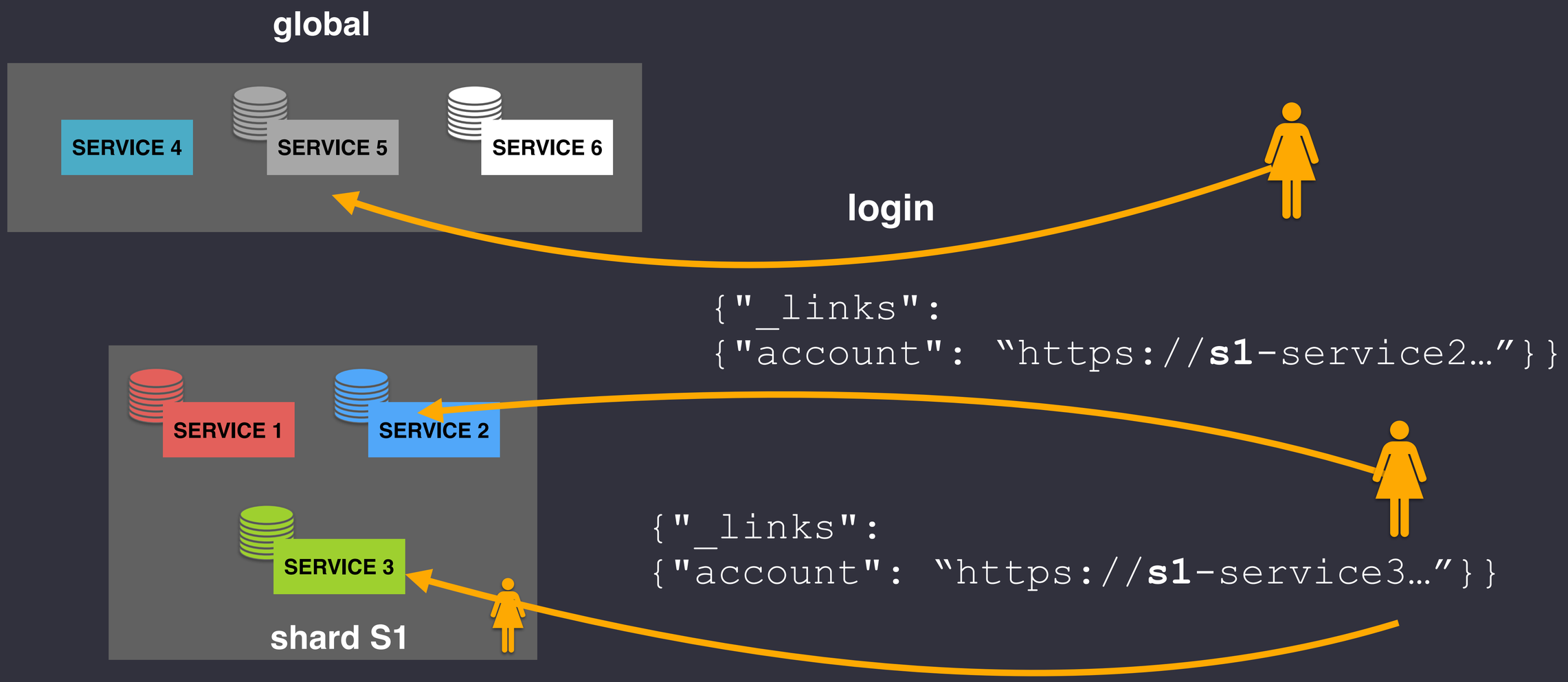


. . .

OPTION #2: SCALABILITY UNITS + GLOBAL ROUTING



OPTION #2: HYPERMEDIA FOR INTERACTIONS



SCALING LESSONS LEARNED

SCALABILITY UNITS WORK

works in practice, but difficult to move incrementally in that direction

AUTOMATED IMMUTABLE INFRA

made this process much more tractable

START EARLY

sharding was a complex project
exponential growth defies intuition: use real growth models for planning

BEWARE HOTSPOTS

business logic may create hot spots
reactivated old prospects overcrowded s0

MESSAGING AND HYPERMEDIA

provide critical flexibility for shard routing

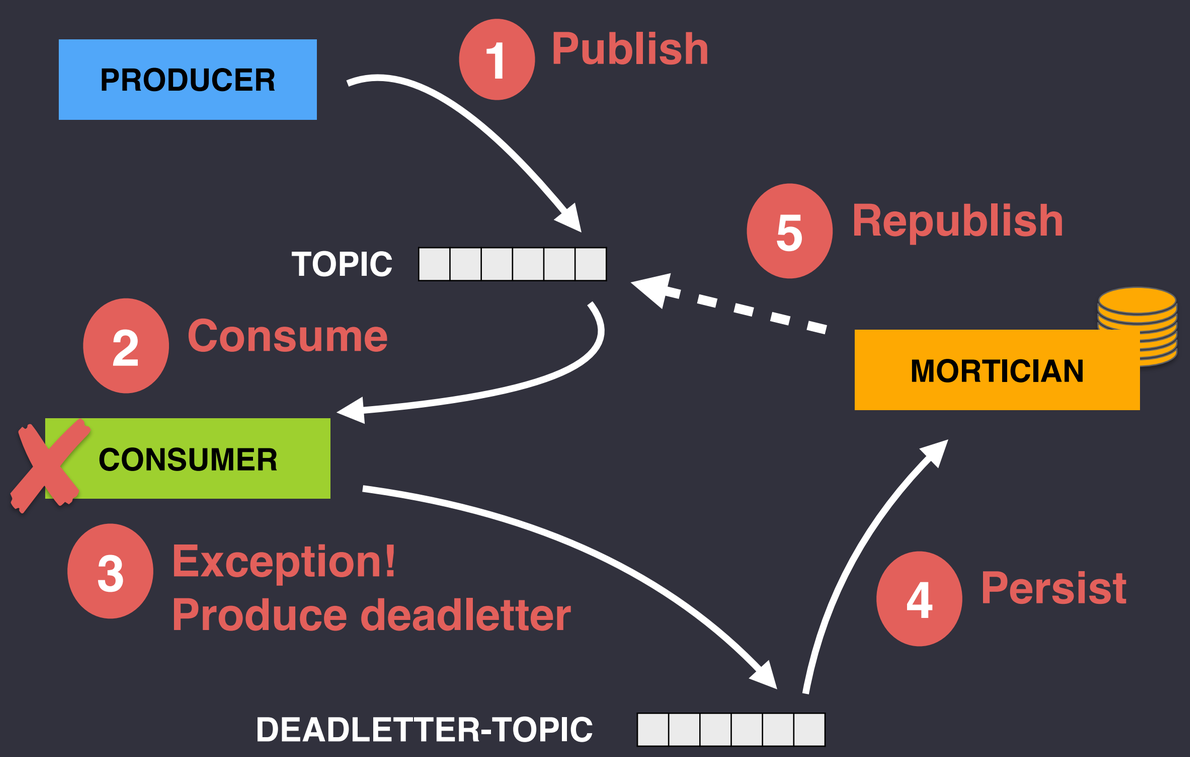
SPLITTING EXISTING DATA

it’s devilishly difficult (we avoided it, mostly)

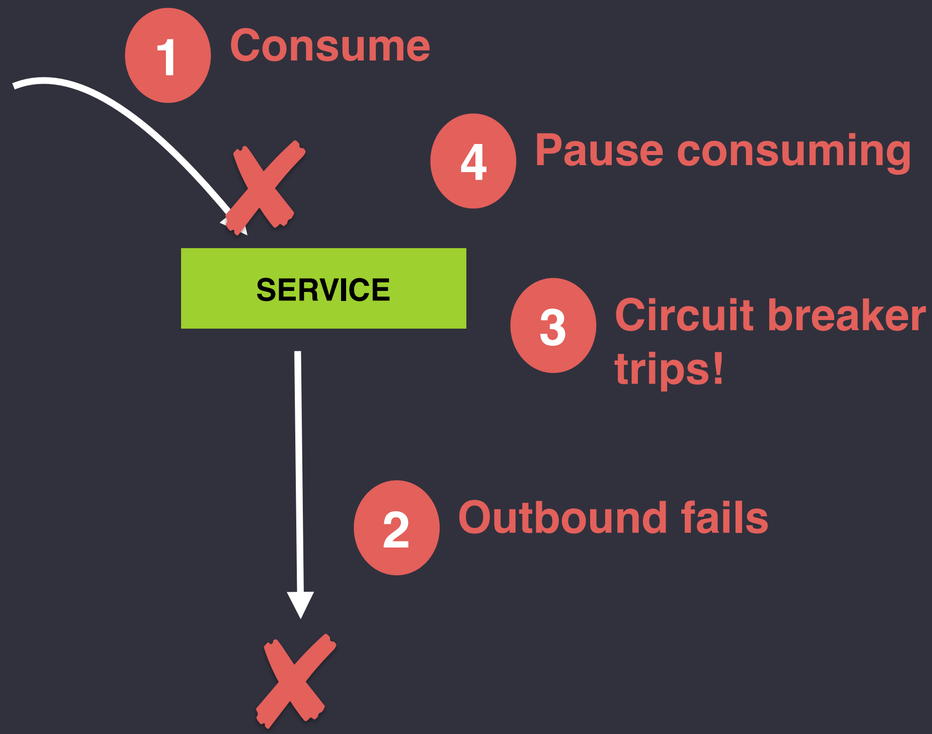
FAULT TOLERANCE PATTERNS

Simple patterns for fault isolation and recovery

DEADLETTERS



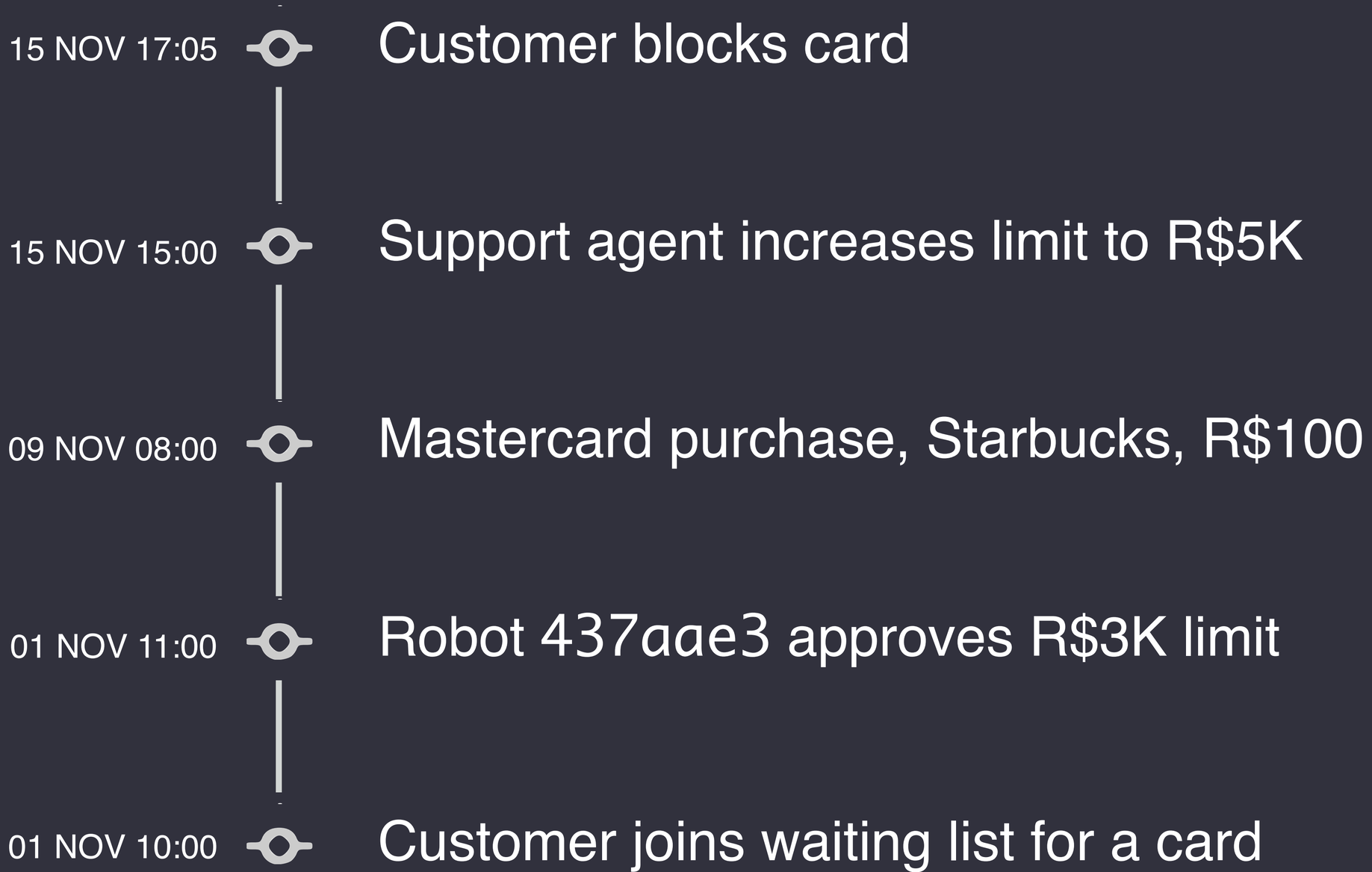
CIRCUIT BREAKERS



ETL + THE ANALYTICAL ENVIRONMENT

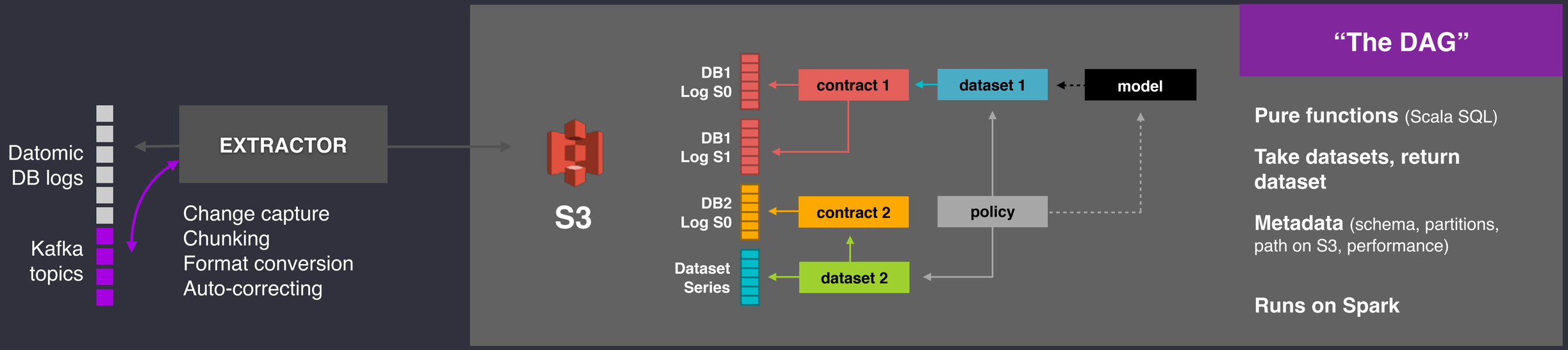
INFRASTRUCTURE

DATOMIC PRIMER: EVENTS OVER TIME



DATOMIC PRIMER: FACTS OVER TIME

EXTRACT, TRANSFORM, LOAD

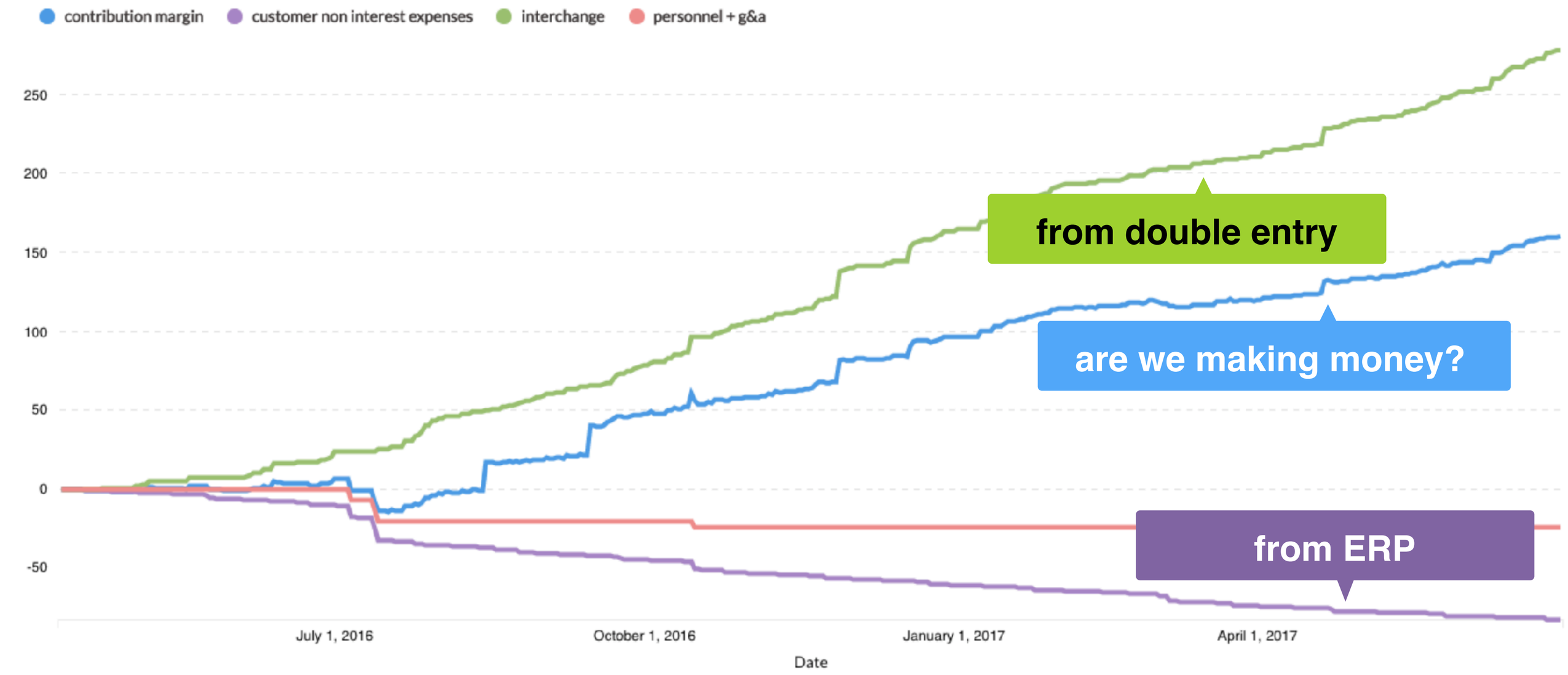


Datomic and Kafka log extraction feeding our data lake (S3) in real time

Analytical schemas (“contracts”) generated from Datomic entities

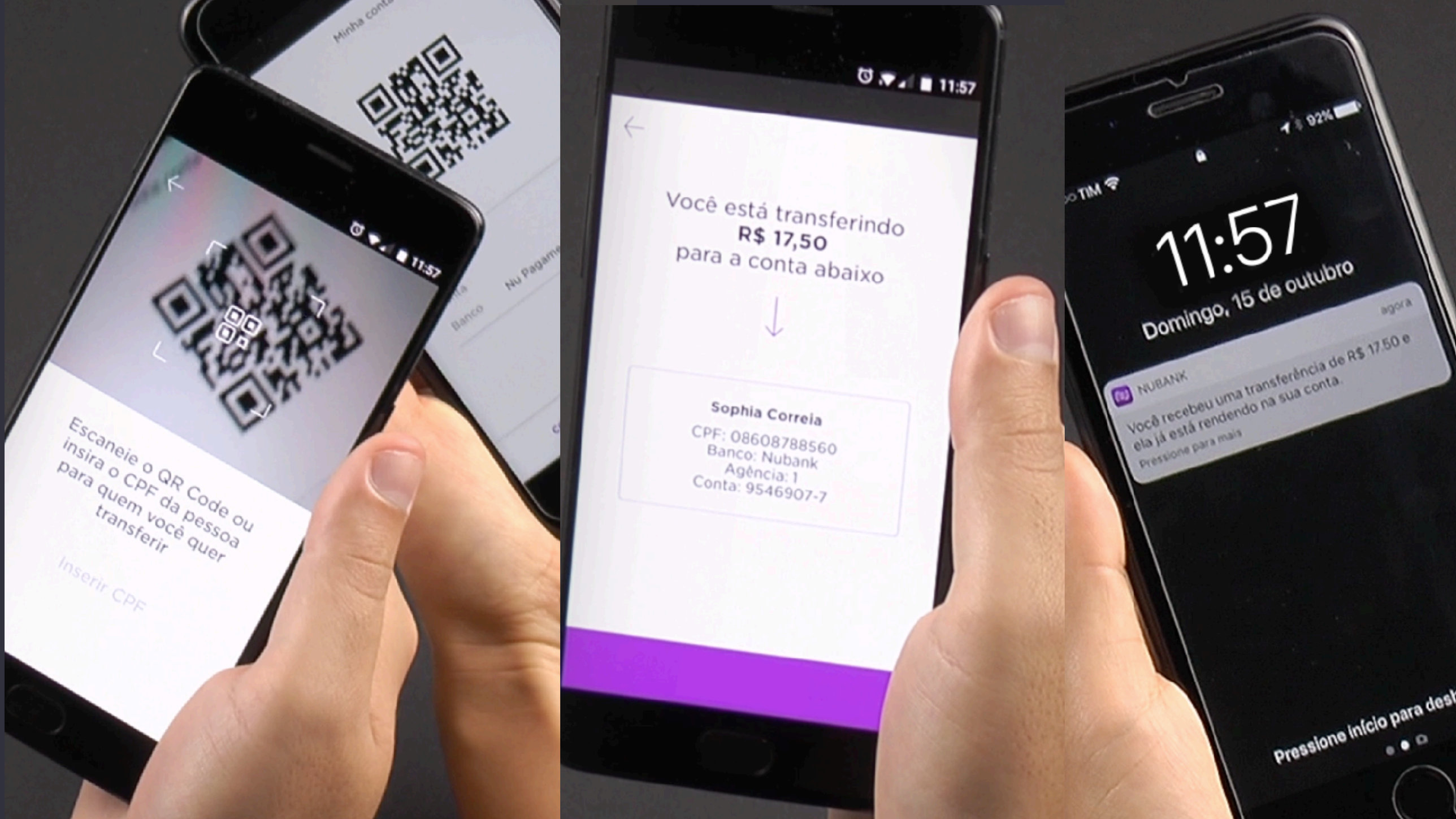
Shards recombined into a logical table-per-entity incrementally

ETL EXAMPLE: CONTRIBUTION MARGIN

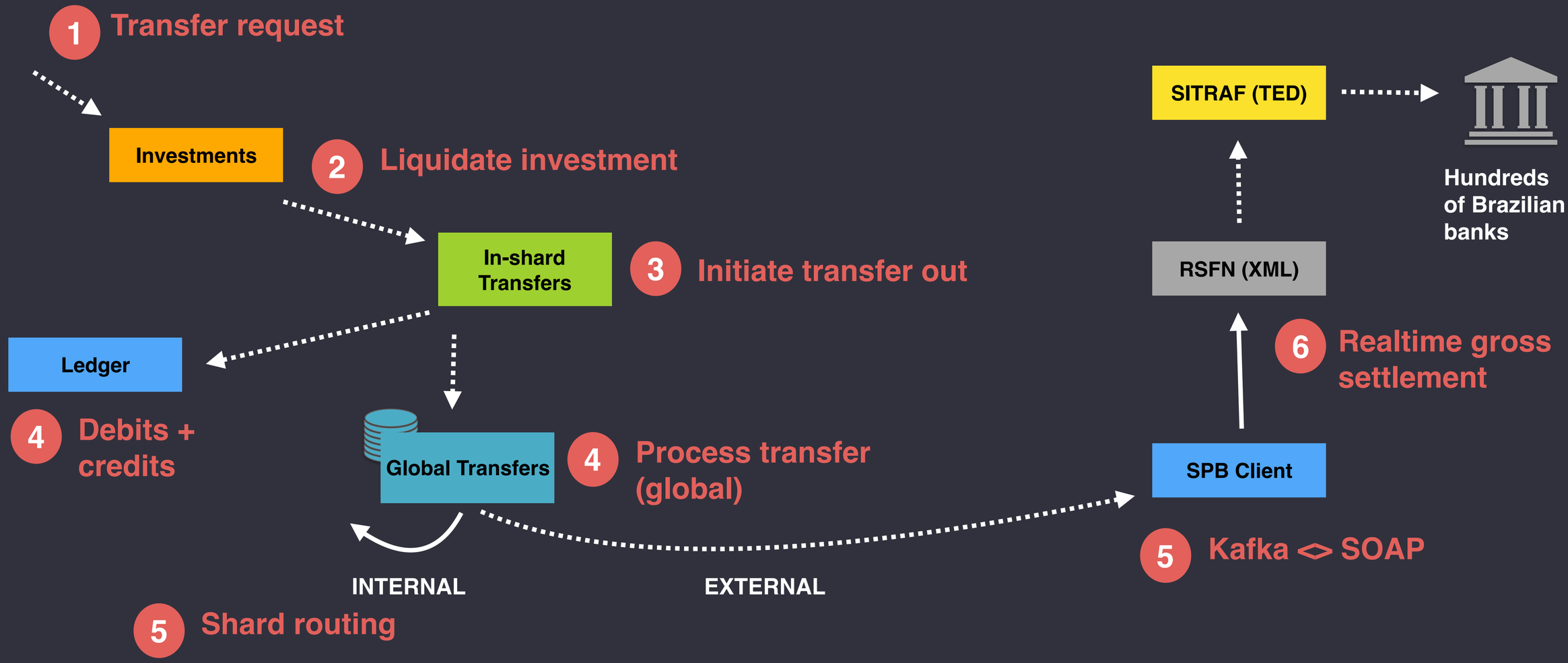


REALTIME TRANSFERS

INFRASTRUCTURE

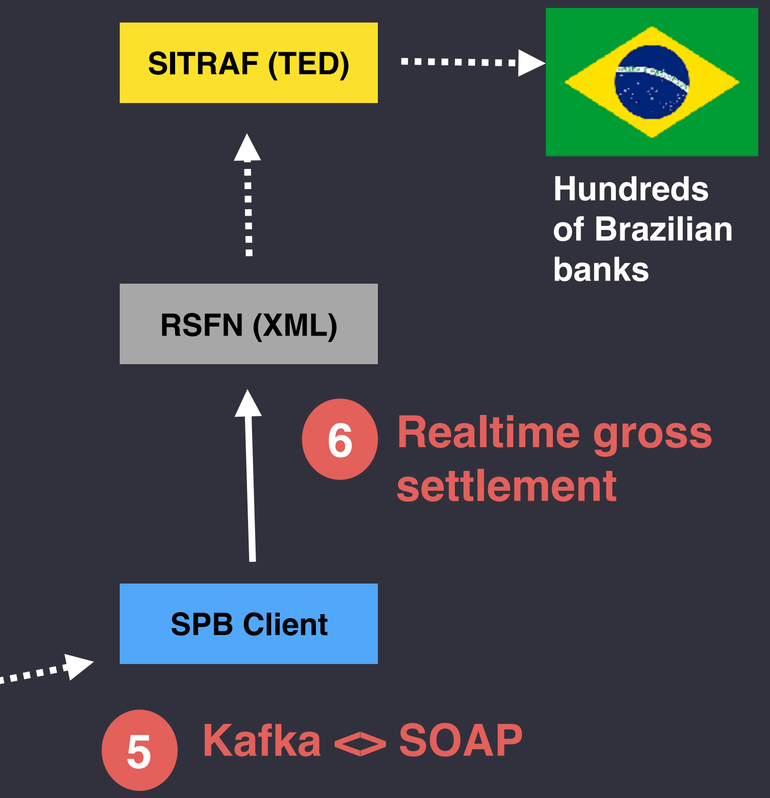

Escaneie o QR Code ou insira o CPF da pessoa para quem você quer transferir
Inserir CPF
Você está transferindo
R$ 17,50
para a conta abaixo
Sophia Correia
CPF: 08608788560
Banco: Nubank
Agência: 1
Conta: 9546907-7
11:57
Domingo, 15 de outubro
NUBANK
agora
Você recebeu uma transferência de R$ 17,50 e ela já está rendendo na sua conta.
Pressione para mais
Pressione início para

REALTIME MONEY TRANSFER



BRAZILIAN PAYMENTS SYSTEM

Hub and spoke model for national payments



Real time gross, irrevocable and unconditional settlement of unlimited amounts

~R$1 trillion (US$300B) transferred per day

06:30 - 18:30 business days

Proprietary XML protocol, IBM MQ Series messaging

See: https://www.bcb.gov.br/Pom/Spb/Ing/Introduction.asp

DOMAIN MODEL SUMMARY

INFRASTRUCTURE


We’re hiring
https://nubank.workable.com
São Paulo, Brazil

We’re hiring

https://nubank.workable.com

Berlin, Germany

nu bank

THANK YOU!

BACKUP

SOUTHEAST BRAZIL REGION FROM SPACE

KEY SECURITY DECISIONS

EXTERNAL

- **Client authentication** (mutual TLS)
  - authorizing new device with reputation score
- **Immutable infrastructure**
  - Short-lived instances
  - No mutations
  - Bootstrap service identity from instance profiles using IAM
- **Uniformity** of service architecture enables rapid patching

INTERNAL

- **Auto-revoke** of access scopes
  - Operational scopes are short lived
  - Customer contact enables access
  - Employee access bootstrapped from Google OAuth, 2FA + Yubikeys required
- **Realtime monitoring** of security events
  - Cloudtrail, Slack, Lambdas for fine-grained operational access control
- Internal **red team** / incident response team

GROWING ORGANICALLY THROUGH REFERRALS

Each customer we book leads to 3-4 new leads