Distributed Sagas

A Protocol for Coordinating Microservices

Caitie McCaffrey

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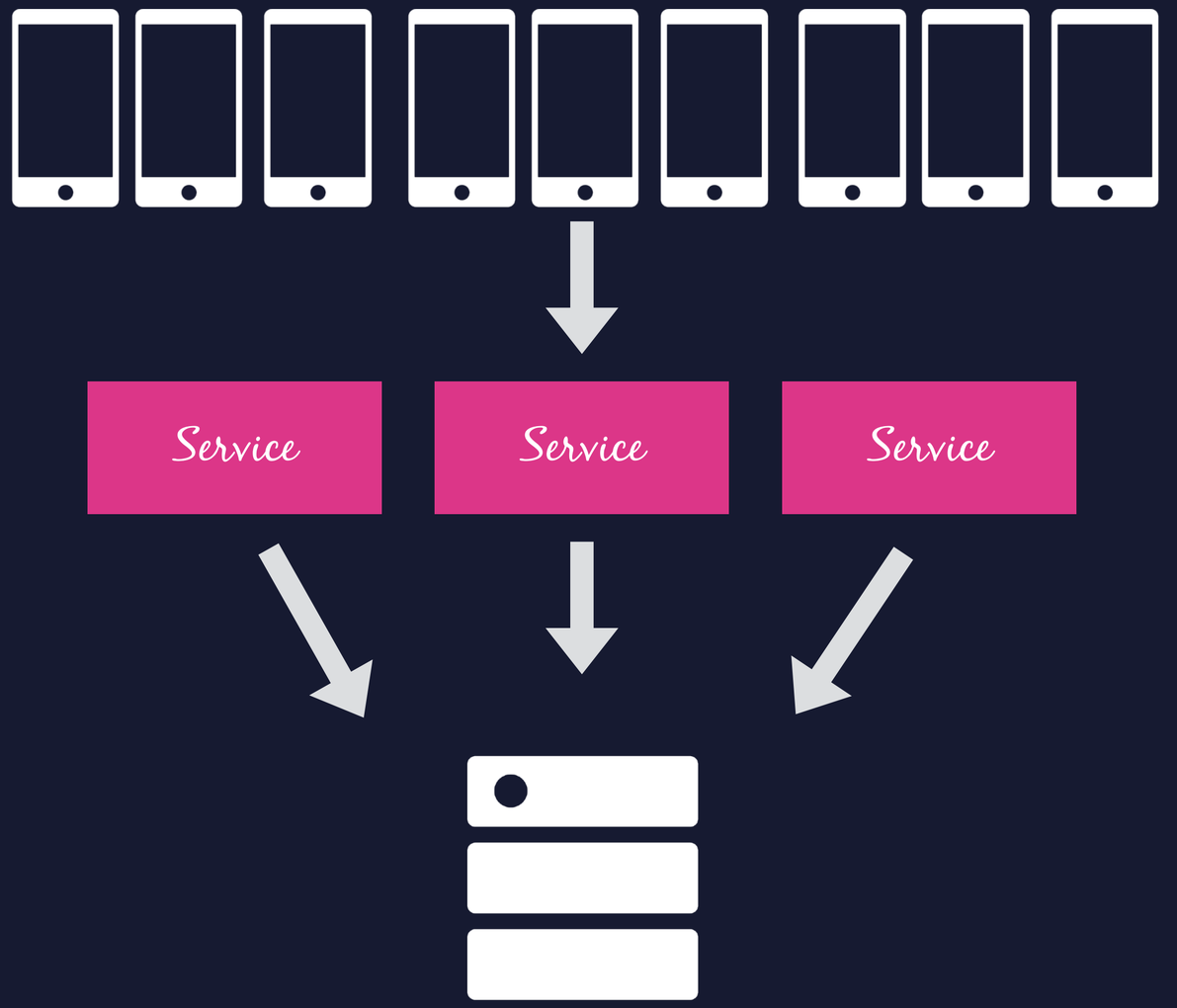
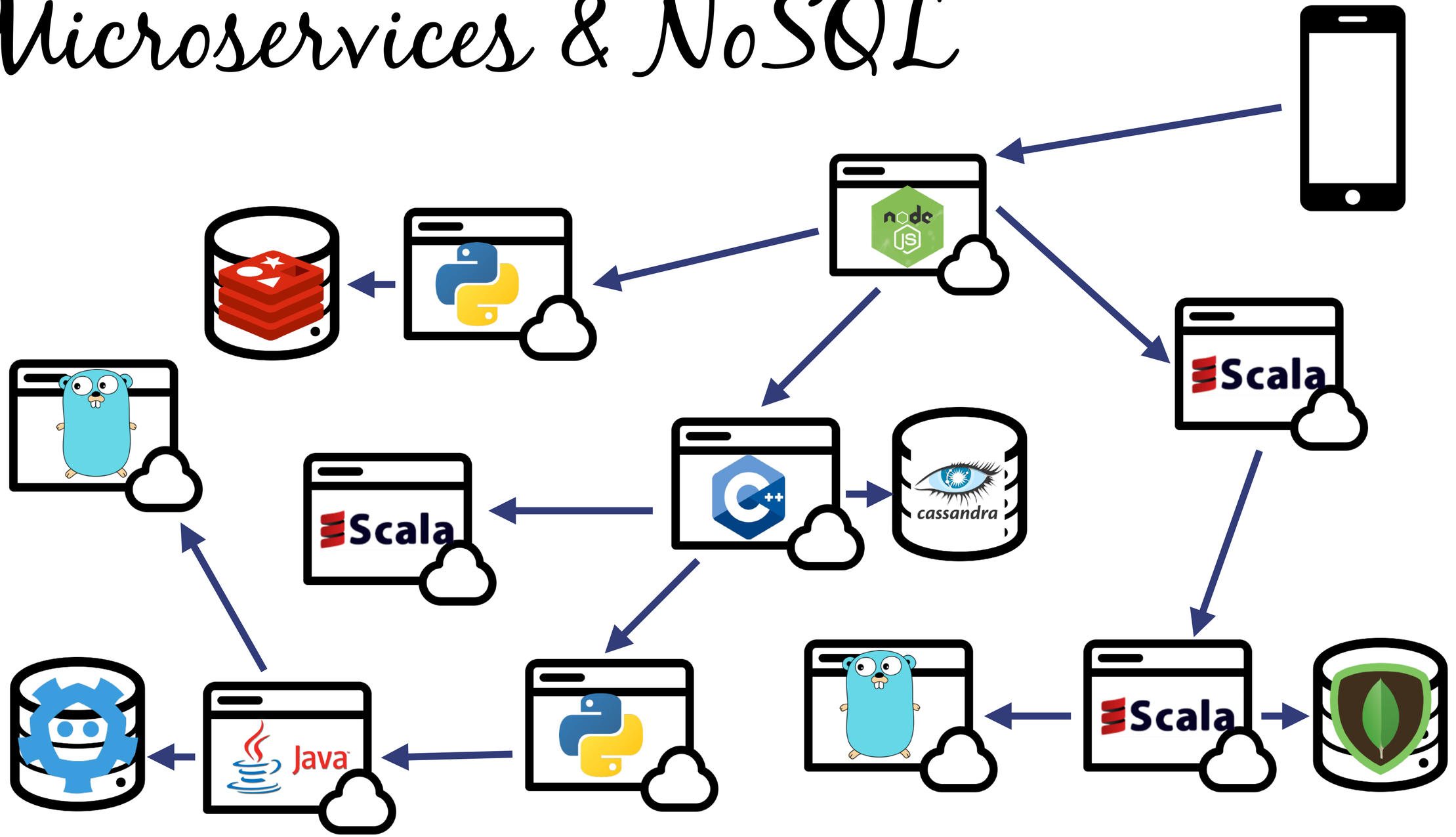
caitiem.com

Monoliths



Microservices & NoSQL



2015

Feral Concurrency Control: An Empirical Investigation of Modern Application Integrity

Peter Bailis, Alan Fekete†, Michael J. Franklin, Ali Ghodsi, Joseph M. Hellerstein, Ion Stoica
UC Berkeley and †University of Sydney

ABSTRACT

The rise of data-intensive "Web 2.0" Internet services has led to a range of popular new programming frameworks that collectively embody the latest incarnation of the vision of Object-Relational Mapping (ORM) systems, albeit at unprecedented scale. In this work, we empirically investigate modern ORM-backed applications' use and disuse of database concurrency control mechanisms. Specifically, we focus our study on the common use of *feral*, or application-level, mechanisms for maintaining database integrity, which, across a range of ORM systems, often take the form of declarative correctness criteria, or invariants. We quantitatively analyze the use of these mechanisms in a range of open source applications written using the Ruby on Rails ORM and find that feral invariants are the most popular means of ensuring integrity (and, by usage, are over 37 times more popular than transactions). We evaluate which of these feral invariants actually ensure integrity (by usage, up to 86.9%) and which—due to concurrency errors and lack of database support—may lead to data corruption (the remainder), which we experimentally quantify. In light of these findings, we present recommendations for database system designers for better supporting

Rails is interesting for at least two reasons. First, it continues to be a popular means of developing responsive web application front-end and business logic, with an active open source community and user base. Rails recently celebrated its tenth anniversary and enjoys considerable commercial interest, both in terms of deployment and the availability of hosted "cloud" environments such as Heroku. Thus, Rails programmers represent a large class of consumers of database technology. Second, and perhaps more importantly, Rails is "opinionated software" [41]. That is, Rails embodies the strong personal convictions of its developer community, and, in particular, David Heinemeier Hansson (known as DHH), its creator. Rails is particularly opinionated towards the database systems that it tasks with data storage. To quote DHH:

> "I don't *want* my database to be clever! . . . I consider stored procedures and constraints vile and reckless destroyers of coherence. No, Mr. Database, you can not have my business logic. Your procedural ambitions will bear no fruit and you'll have to pry that logic from my dead, cold object-oriented hands . . . I want a single layer of cleverness: My domain model." [55]

2015

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"Application-level Mechanisms for maintaining database integrity"

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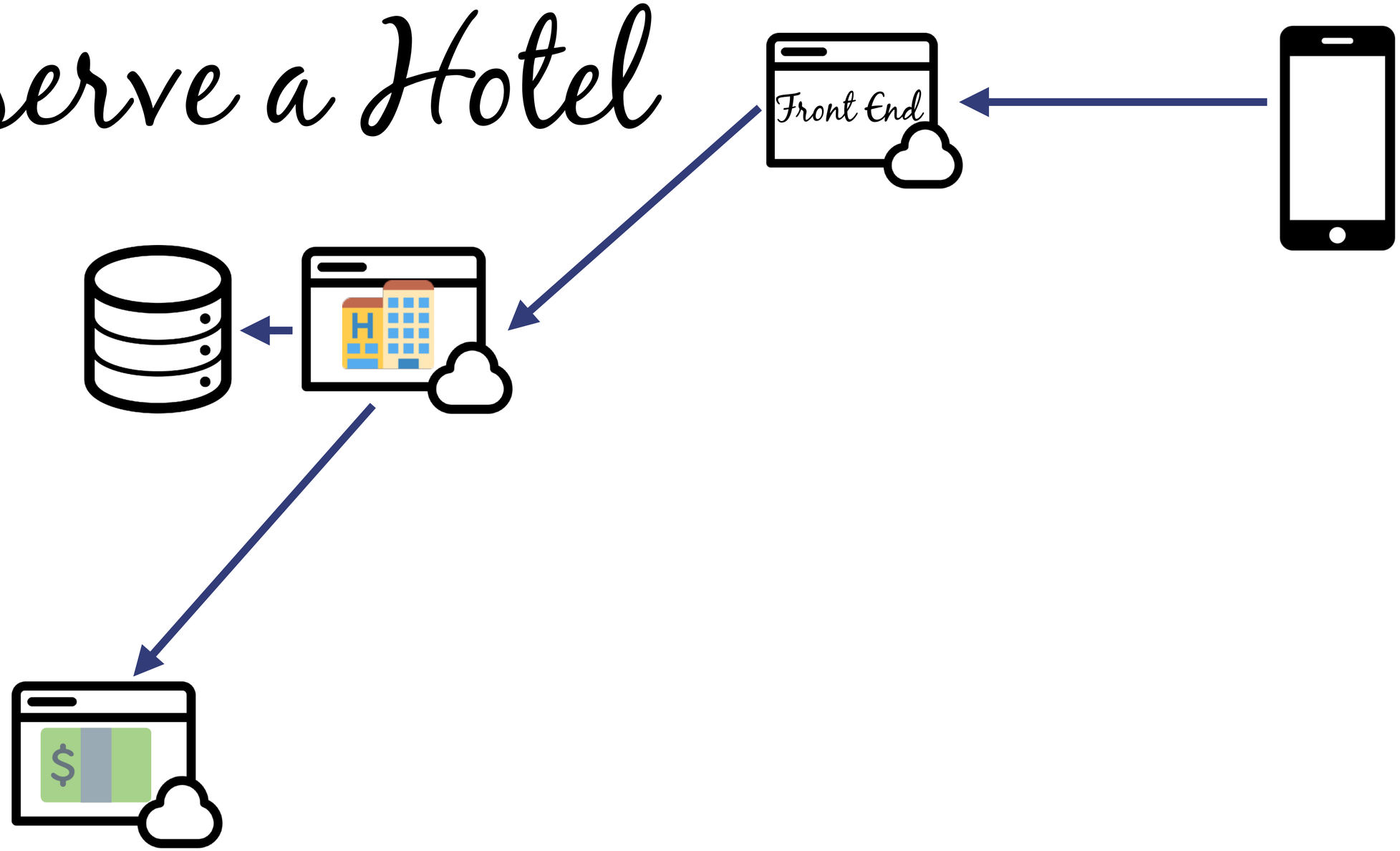
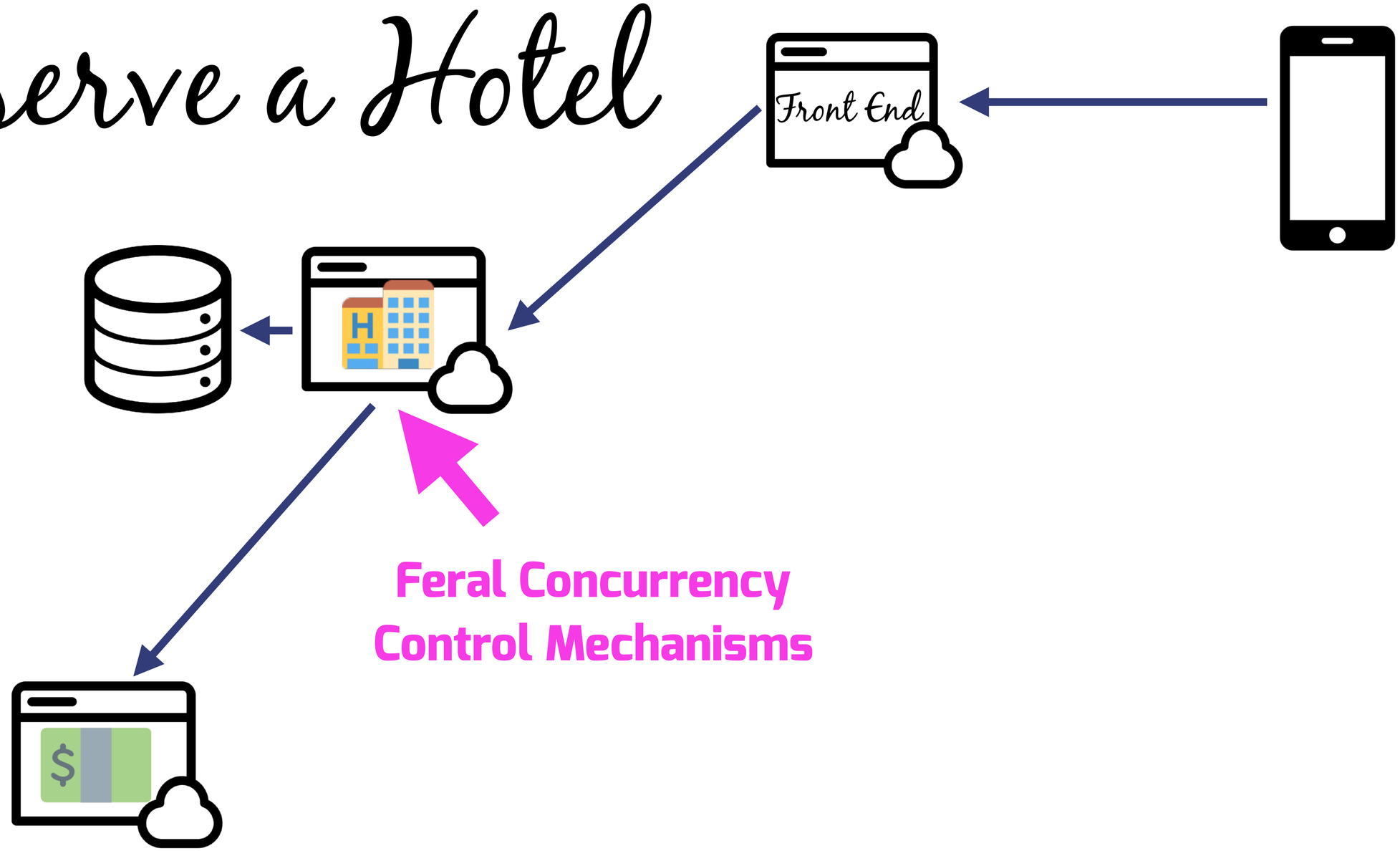
Reserve a Hotel

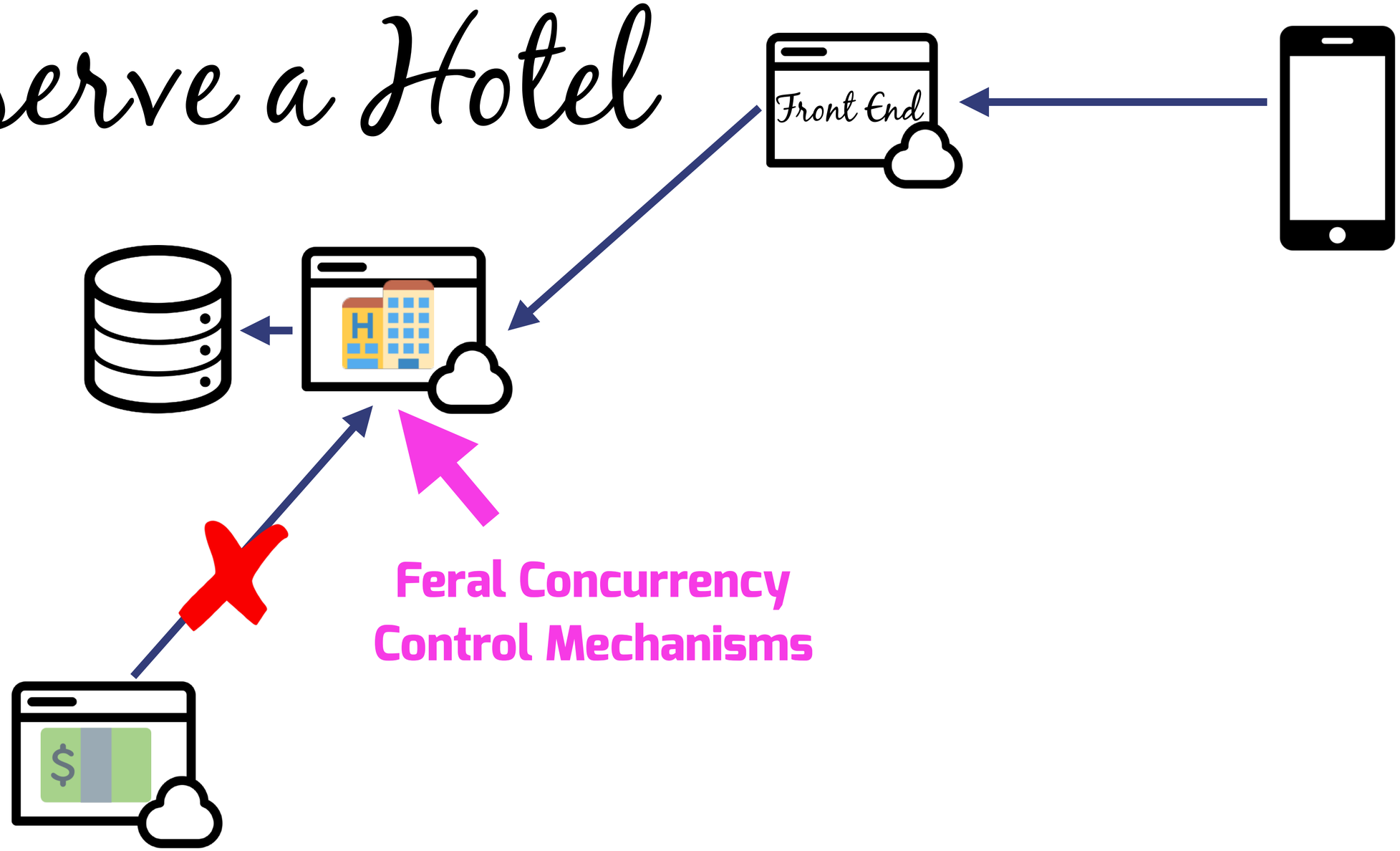


Reserve a Hotel

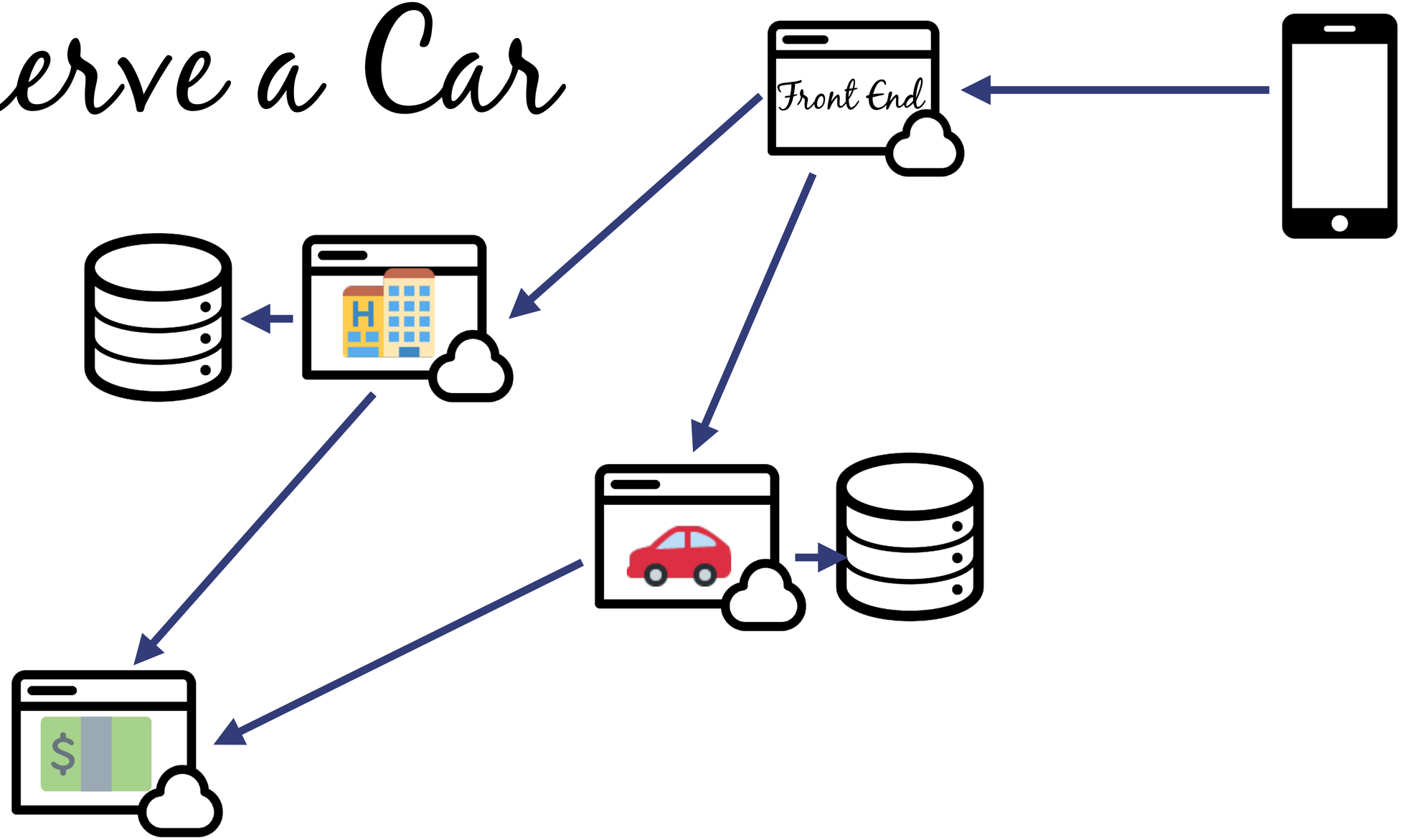


Feral Concurrency Control Mechanisms

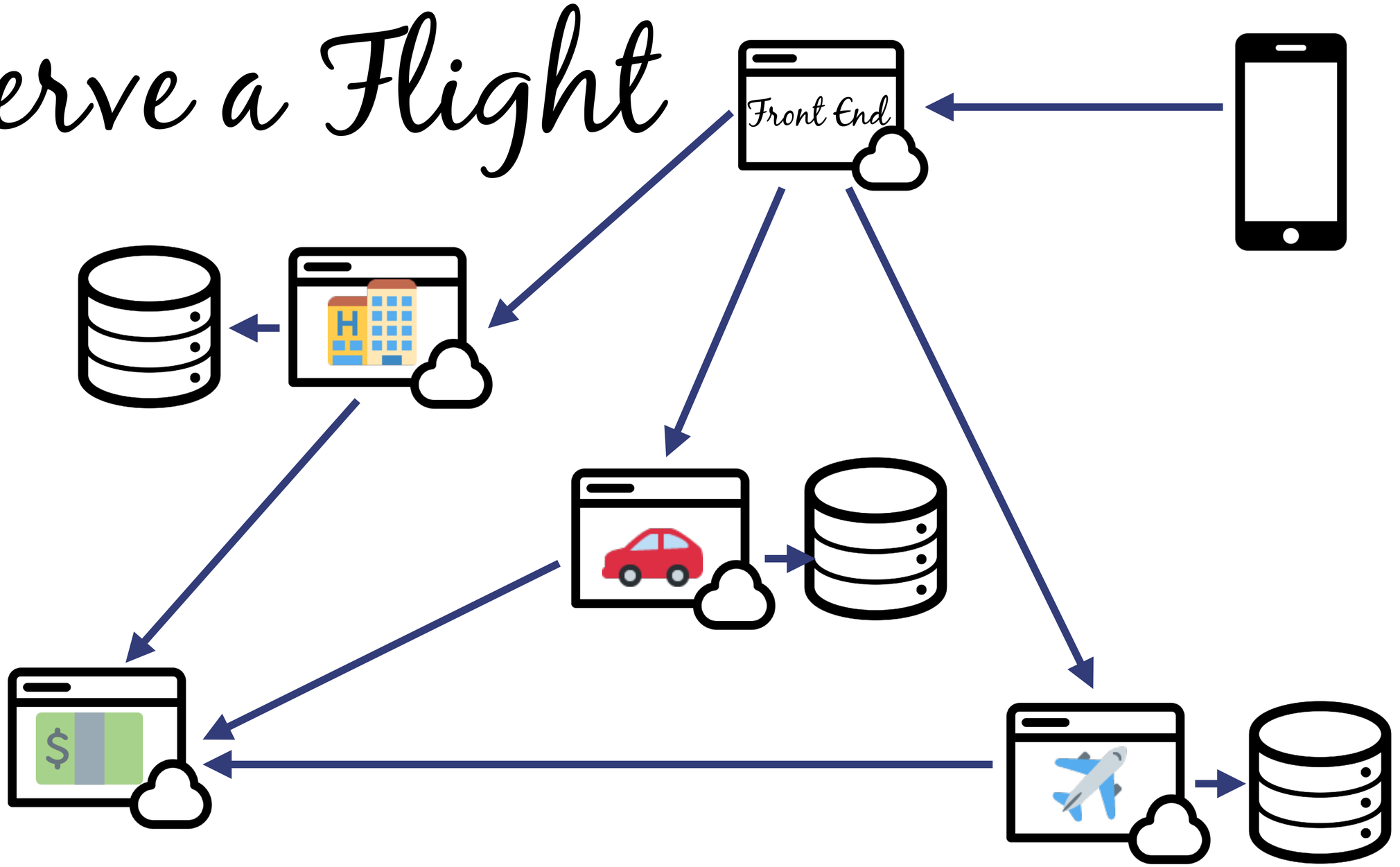
Reserve a Hotel



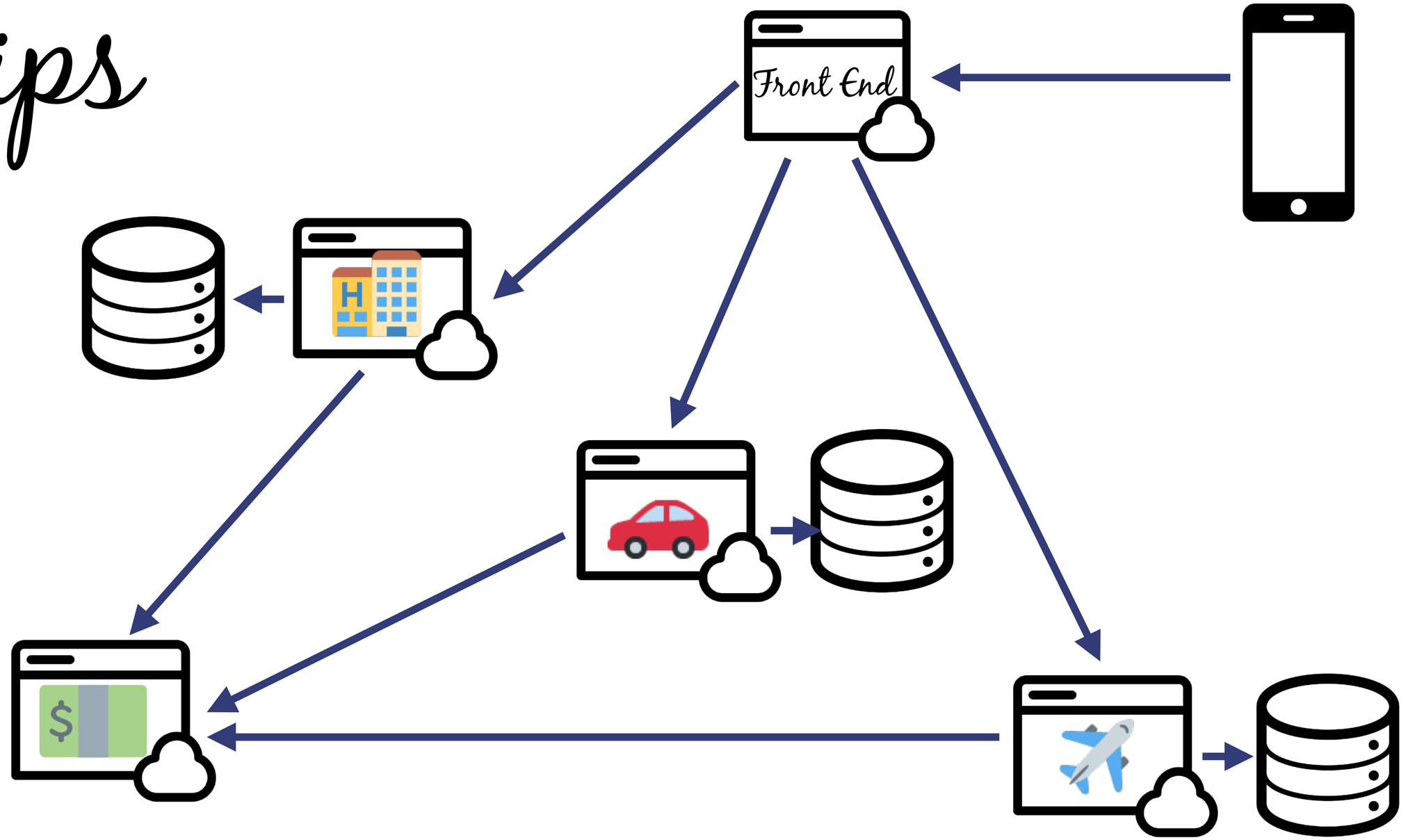
Reserve a Car



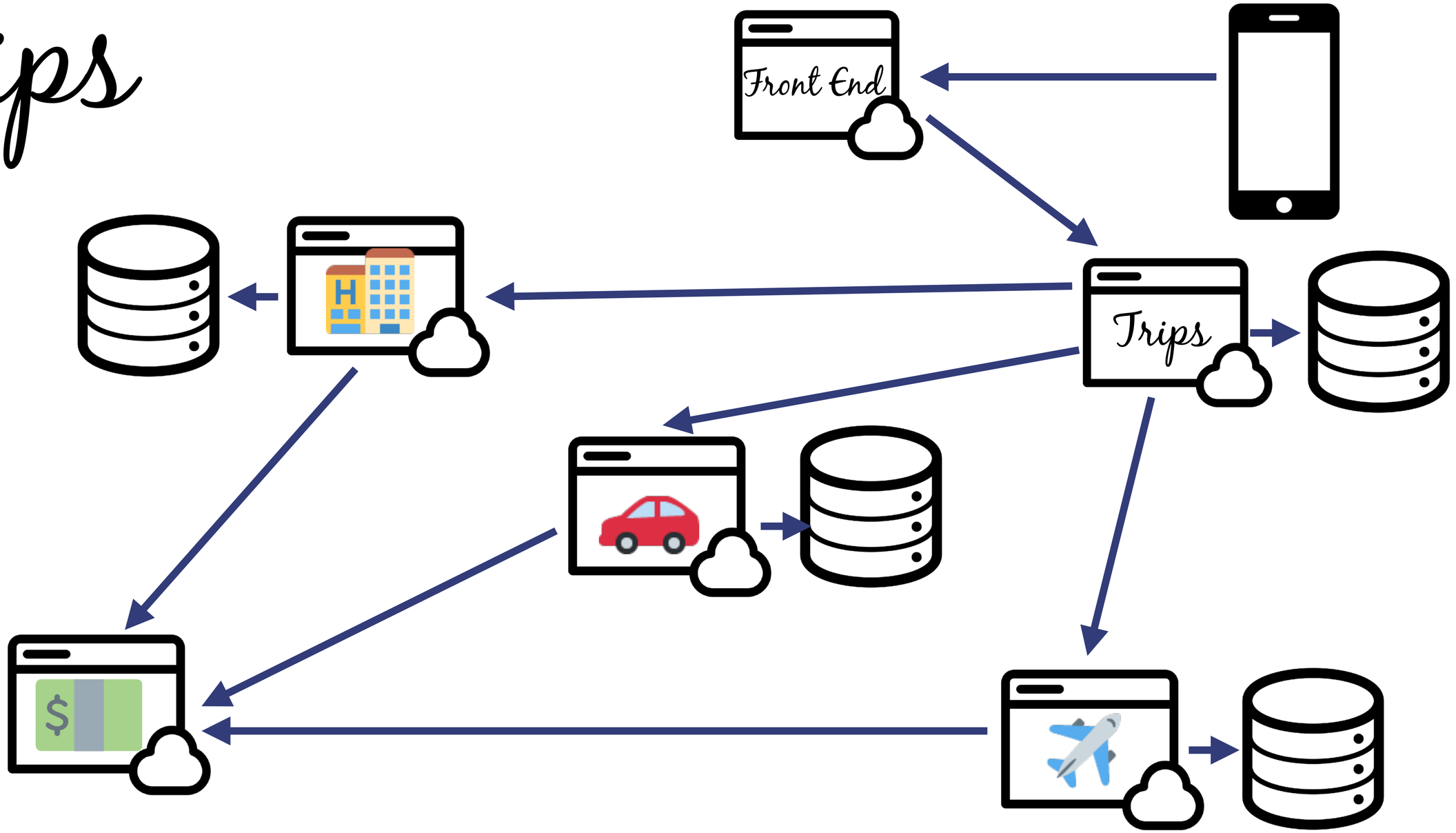
Reserve a Flight



Trips



Trips



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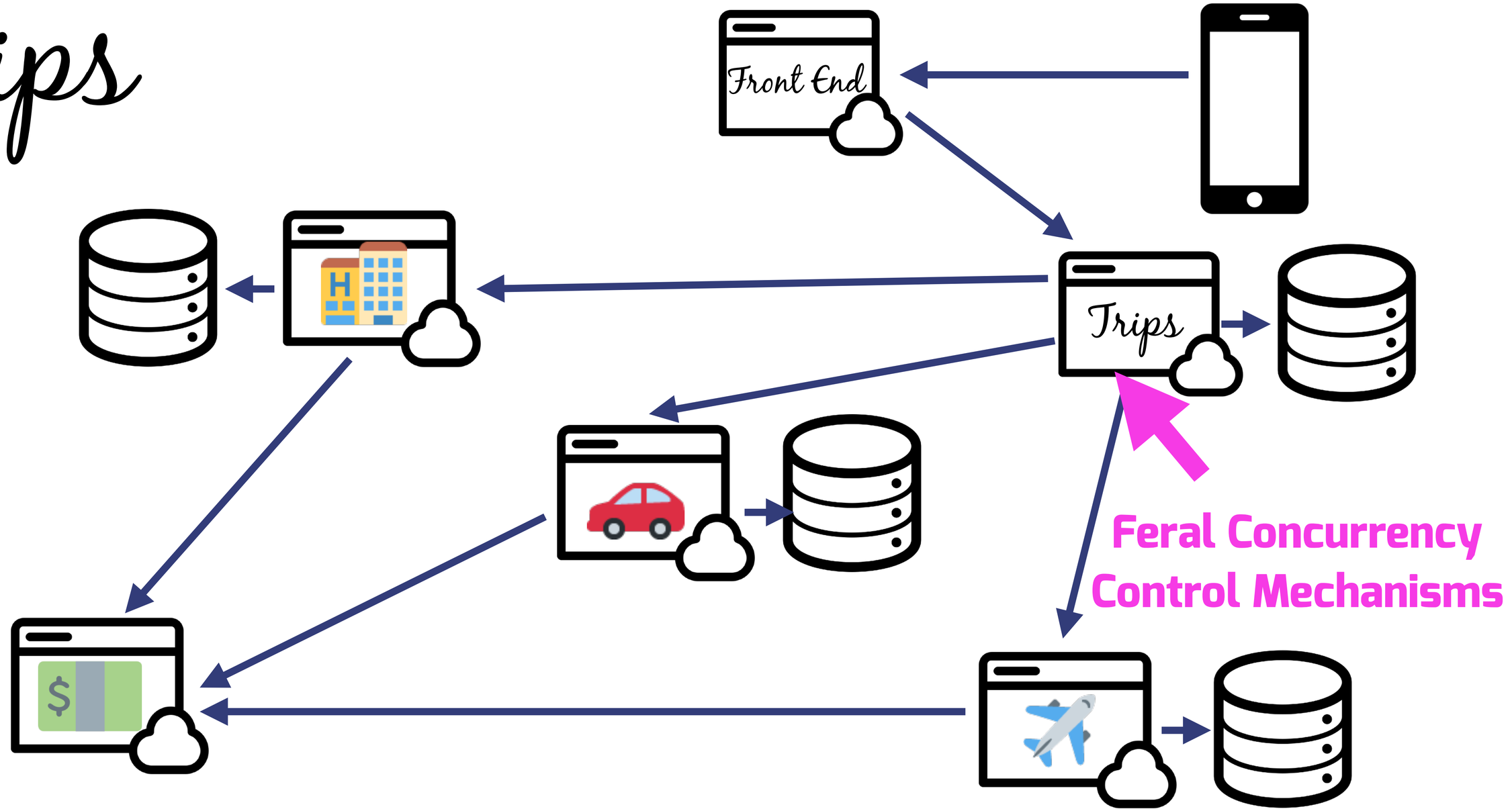

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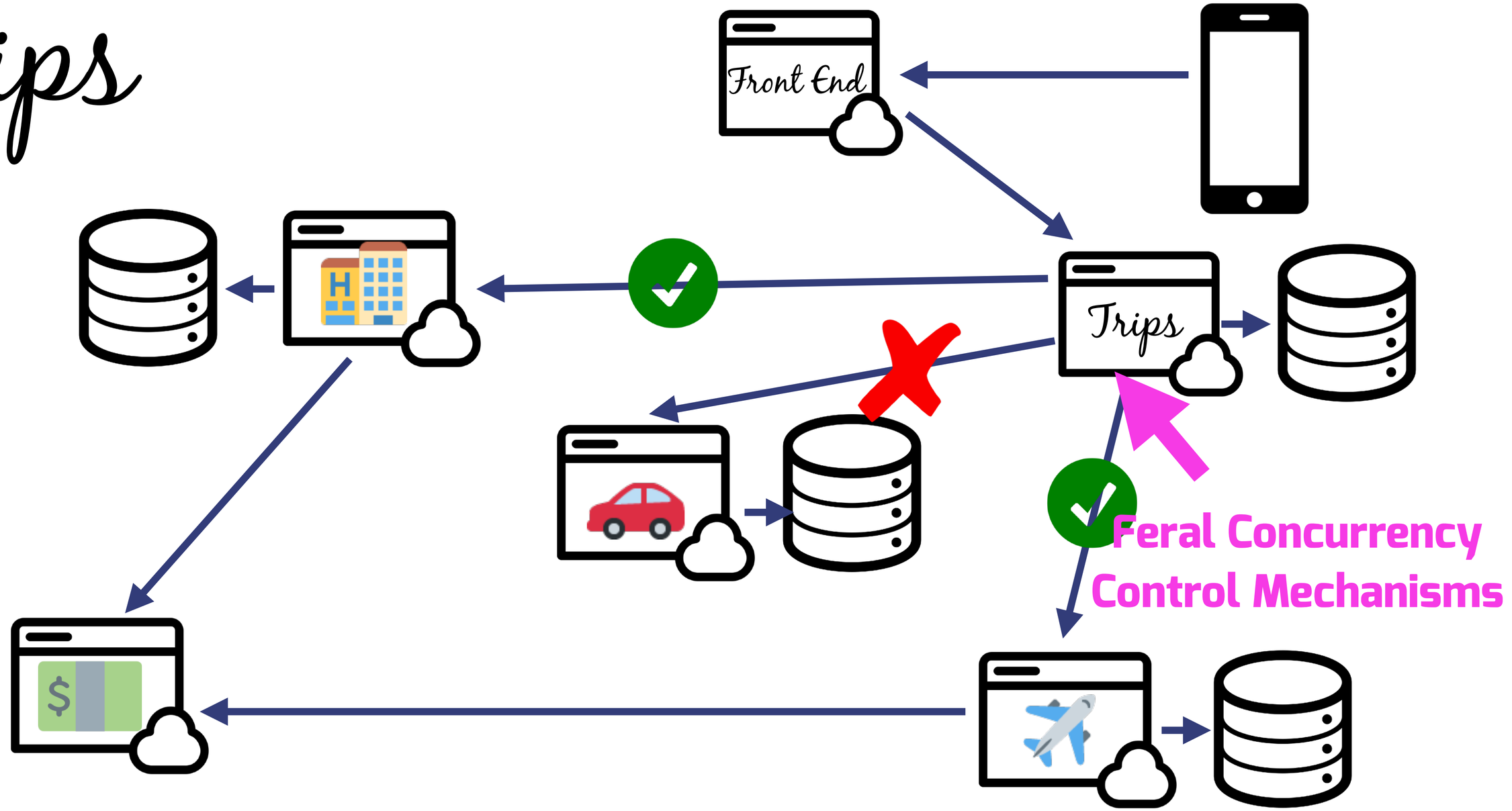
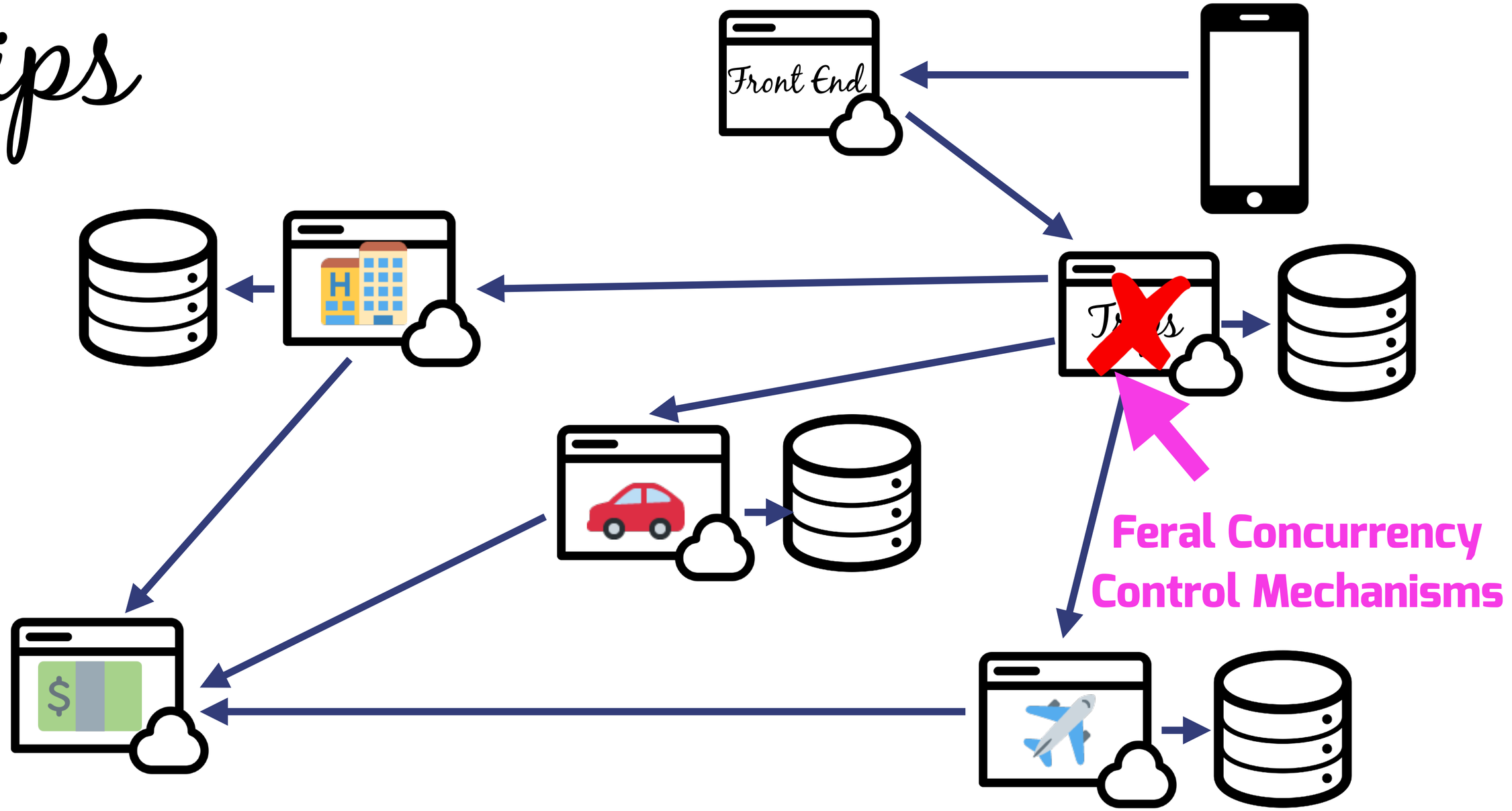
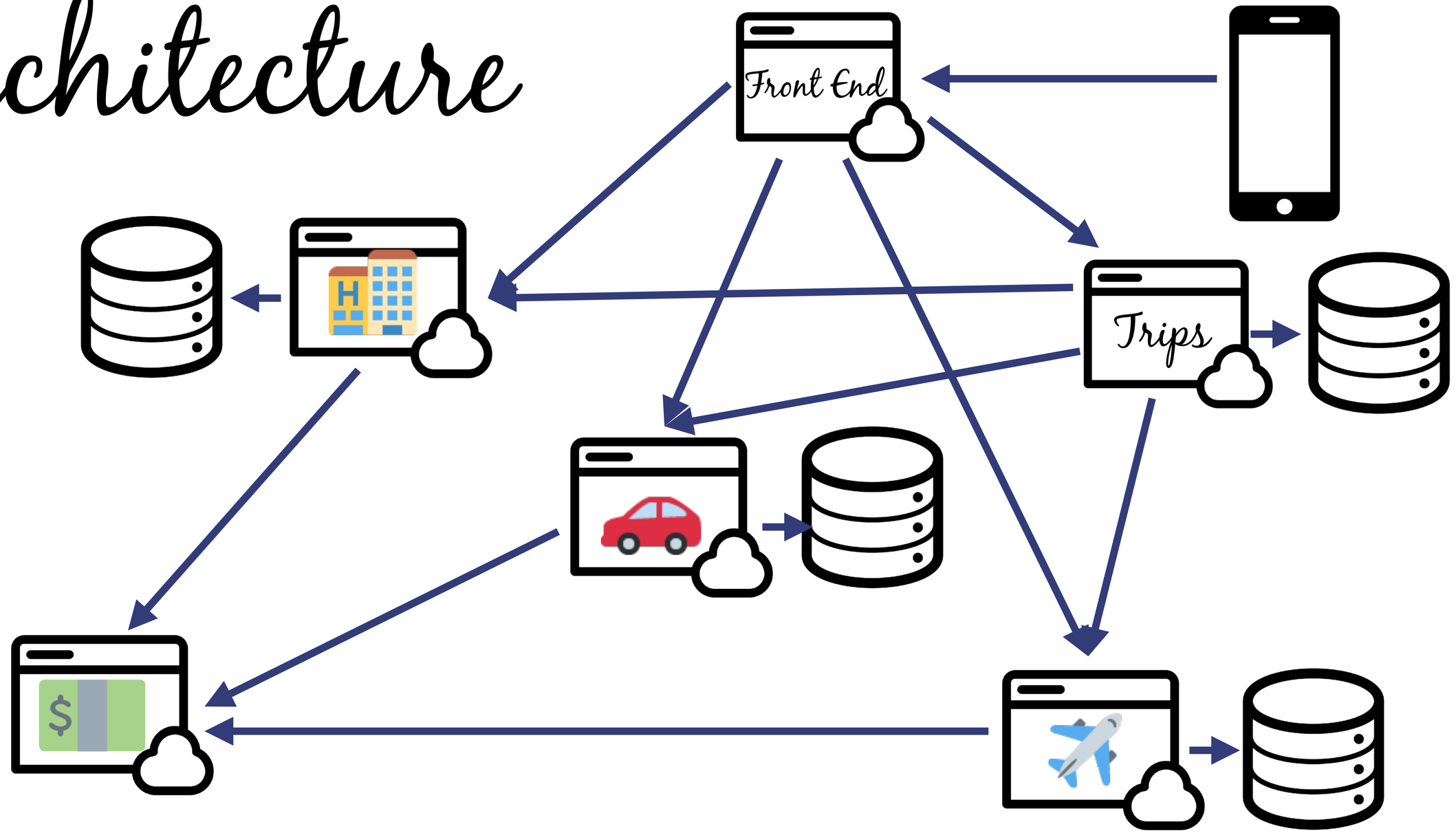


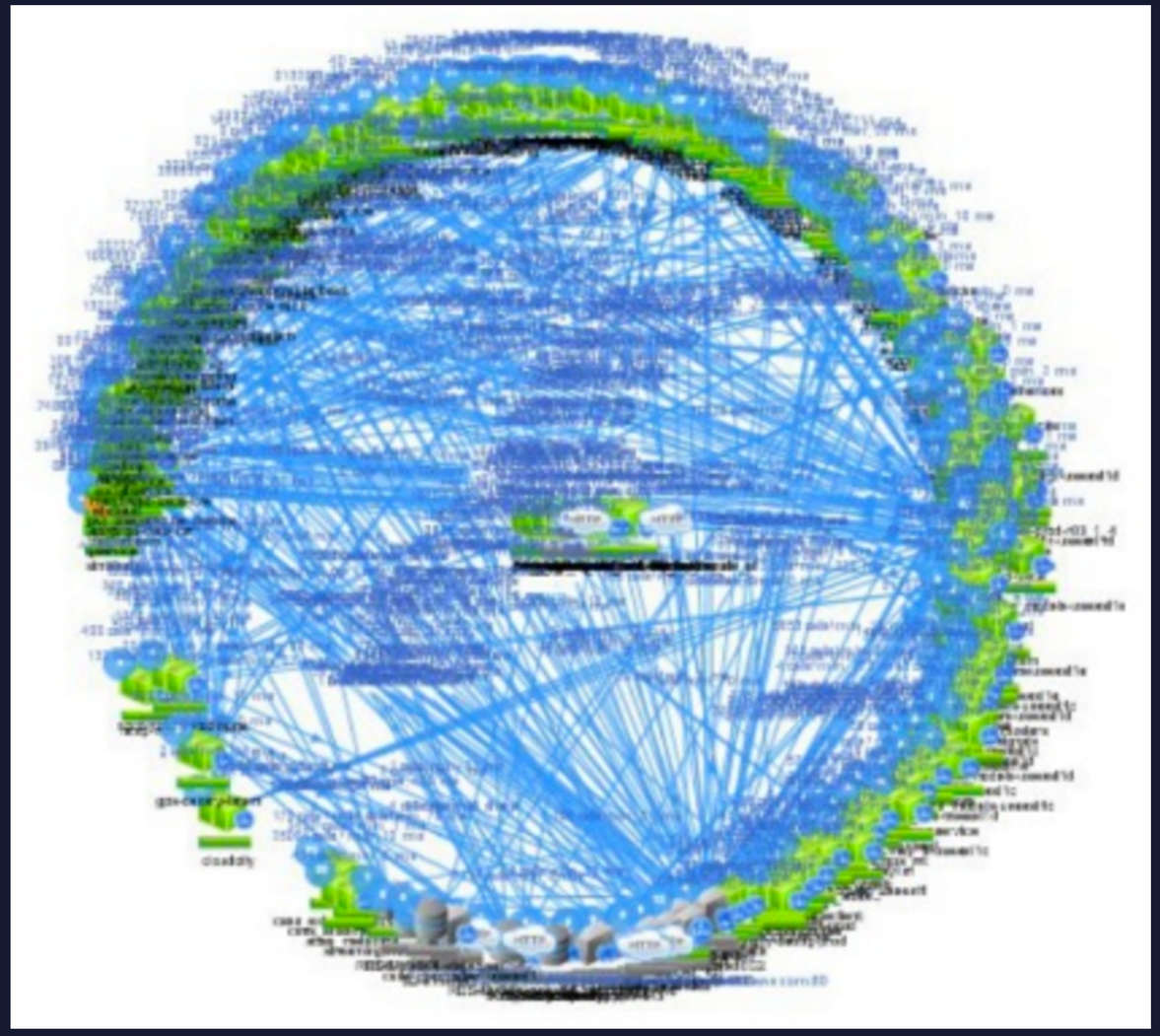
Trips

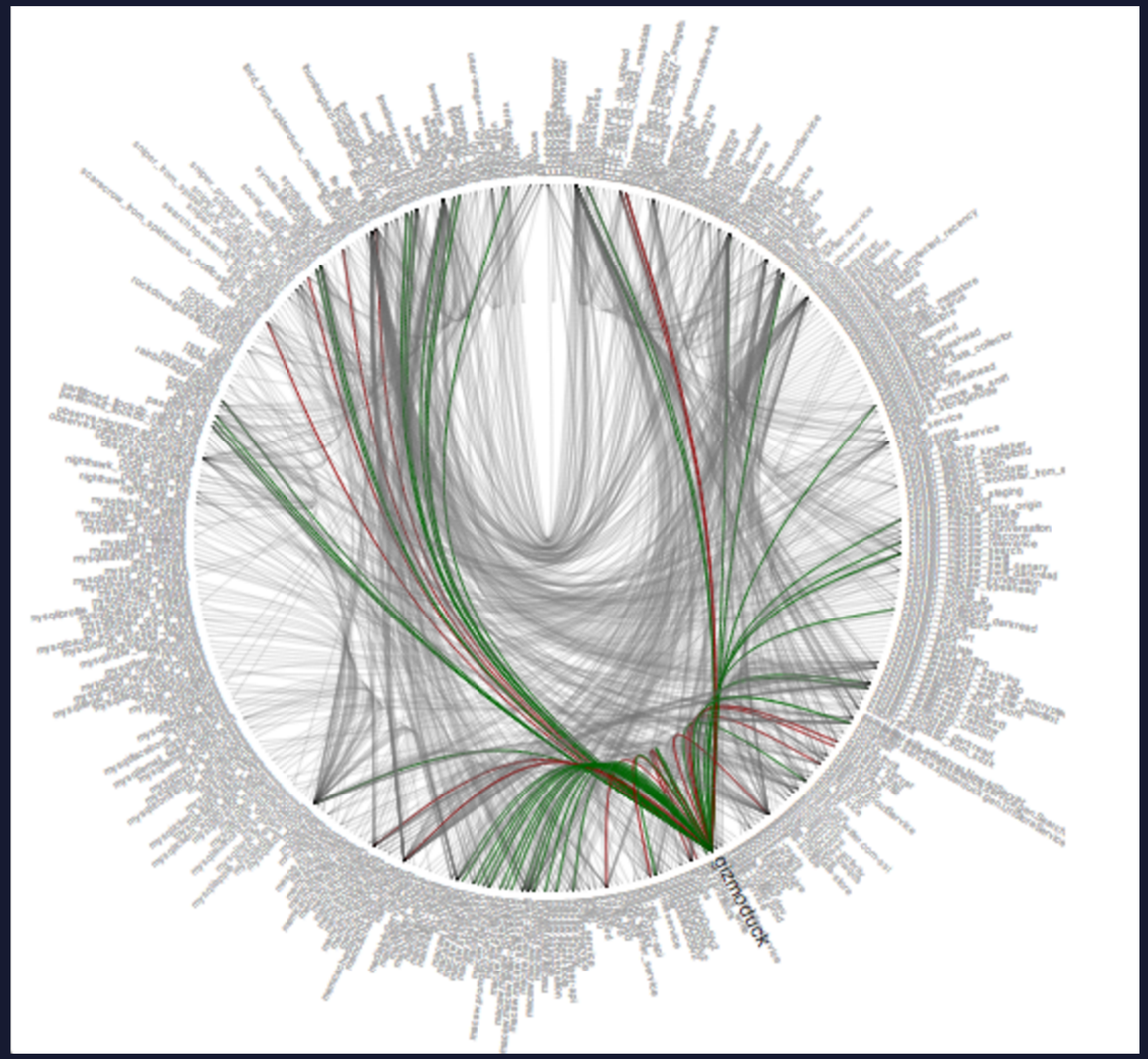


Architecture



Death Star Architectures





Can We Do Better

than Feral Concurrency Control?

2012

Spanner: Google's Globally-Distributed Database

James C. Corbett, Jeffrey Dean, Michael Epstein, Andrew Fikes, Christopher Frost, JJ Furman, Sanjay Ghemawat, Andrey Gubarev, Christopher Heiser, Peter Hochschild, Wilson Hsieh, Sebastian Kanthak, Eugene Kogan, Hongyi Li, Alexander Lloyd, Sergey Melnik, David Mwaura, David Nagle, Sean Quinlan, Rajesh Rao, Lindsay Rolig, Yasushi Saito, Michal Szymaniak, Christopher Taylor, Ruth Wang, Dale Woodford

Google, Inc.

Abstract

Spanner is Google's scalable, multi-version, globally-distributed, and synchronously-replicated database. It is the first system to distribute data at global scale and support externally-consistent distributed transactions. This paper describes how Spanner is structured, its feature set, the rationale underlying various design decisions, and a novel time API that exposes clock uncertainty. This API and its implementation are critical to supporting external consistency and a variety of powerful features: non-blocking reads in the past, lock-free read-only transactions, and atomic schema changes, across all of Spanner.

1 Introduction

tency over higher availability, as long as they can survive 1 or 2 datacenter failures.

Spanner's main focus is managing cross-datacenter replicated data, but we have also spent a great deal of time in designing and implementing important database features on top of our distributed-systems infrastructure. Even though many projects happily use Bigtable [9], we have also consistently received complaints from users that Bigtable can be difficult to use for some kinds of applications: those that have complex, evolving schemas, or those that want strong consistency in the presence of wide-area replication. (Similar claims have been made by other authors [37].) Many applications at Google have chosen to use Megastore [5] because of its semi-relational data model and support for synchronous repli-

2012

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"Spanner is Google's scalable, multi-version, globally distributed, and synchronously-replicated database"

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1 Introduction

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2015

Challenges to Adopting Stronger Consistency at Scale

Phillipe Ajoux*, Nathan Bronson*, Sanjeev Kumar*, Wyatt Lloyd†*, Kaushik Veeraraghavan*
*Facebook, †University of Southern California

Abstract

There have been many recent advances in distributed systems that provide stronger semantics for geo-replicated data stores like those underlying Facebook. These research systems provide a range of consistency models and transactional abilities while demonstrating good performance and scalability on experimental workloads. At Facebook we are excited by these lines of research, but fundamental and operational challenges currently make it infeasible to incorporate these advances into deployed systems. This paper describes some of these challenges with the hope that future advances will address them.

1 Introduction

Facebook is a social network that connects 1.35 billion people [19]. Facebook's social graph reflects its users, their relationships, the content they create, and the actions they take. The social graph is large and constantly growing and changing. Data from this graph is stored in several geo-replicated data stores and tightly integrated services such as Search and News Feed. No single data placement strategy can efficiently serve all workloads in a heavily sharded system, so many of these services choose a specialized sharding function and maintain their own data store, caches, and indexes.

The biggest barrier to providing stronger consistency guarantees in an environment like Facebook's is that the consistency mechanism must **integrate consistency across many stateful services**. All of the scaling mechanisms described above lead to extra copies of data. Even if each of our caches and independent services were linearizable [24], inconsistencies would still be present in the aggregated result. Inter-service tracking is complicated by services that store data derived from a query to a lower layer, making object-level tracking insufficient. While these challenges are acute for Facebook at its present scale, we first encountered them when Facebook was much smaller. Solutions to these problems will benefit the growing class of applications whose implementation relies on sharding and separation into stateful services.

Another fundamental challenge is that a general consistency mechanism at scale must **tolerate high query**

2015

Challenges to Adopting Stronger Consistency at Scale

Phillipe Ajoux*, Nathan Bronson*, Sanjeev Kumar*, Wyatt Lloyd†*, Kaushik Veeraraghavan*
*Facebook, †University of Southern California

"The biggest barrier...is that consistency mechanisms must integrate across many stateful services"

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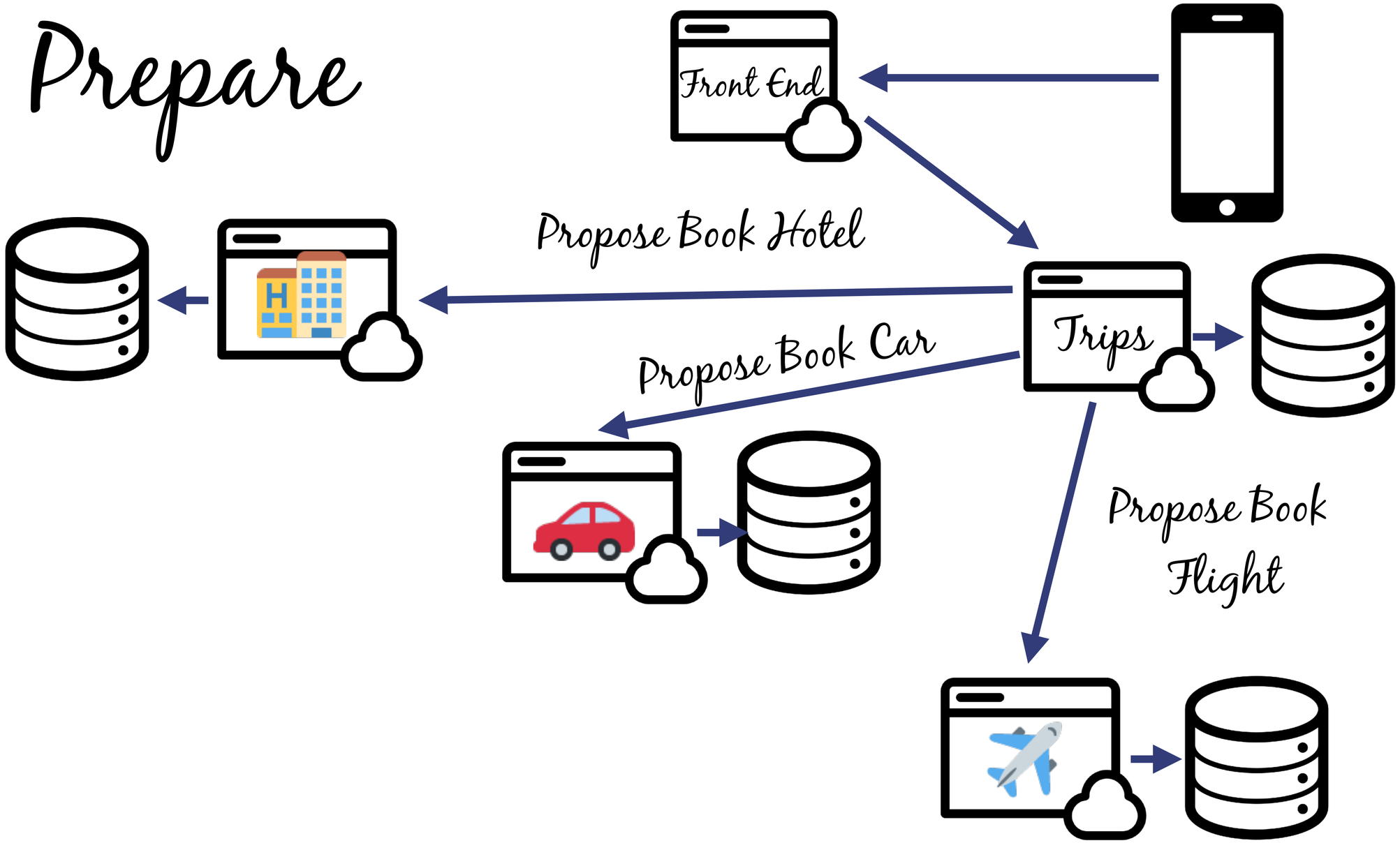
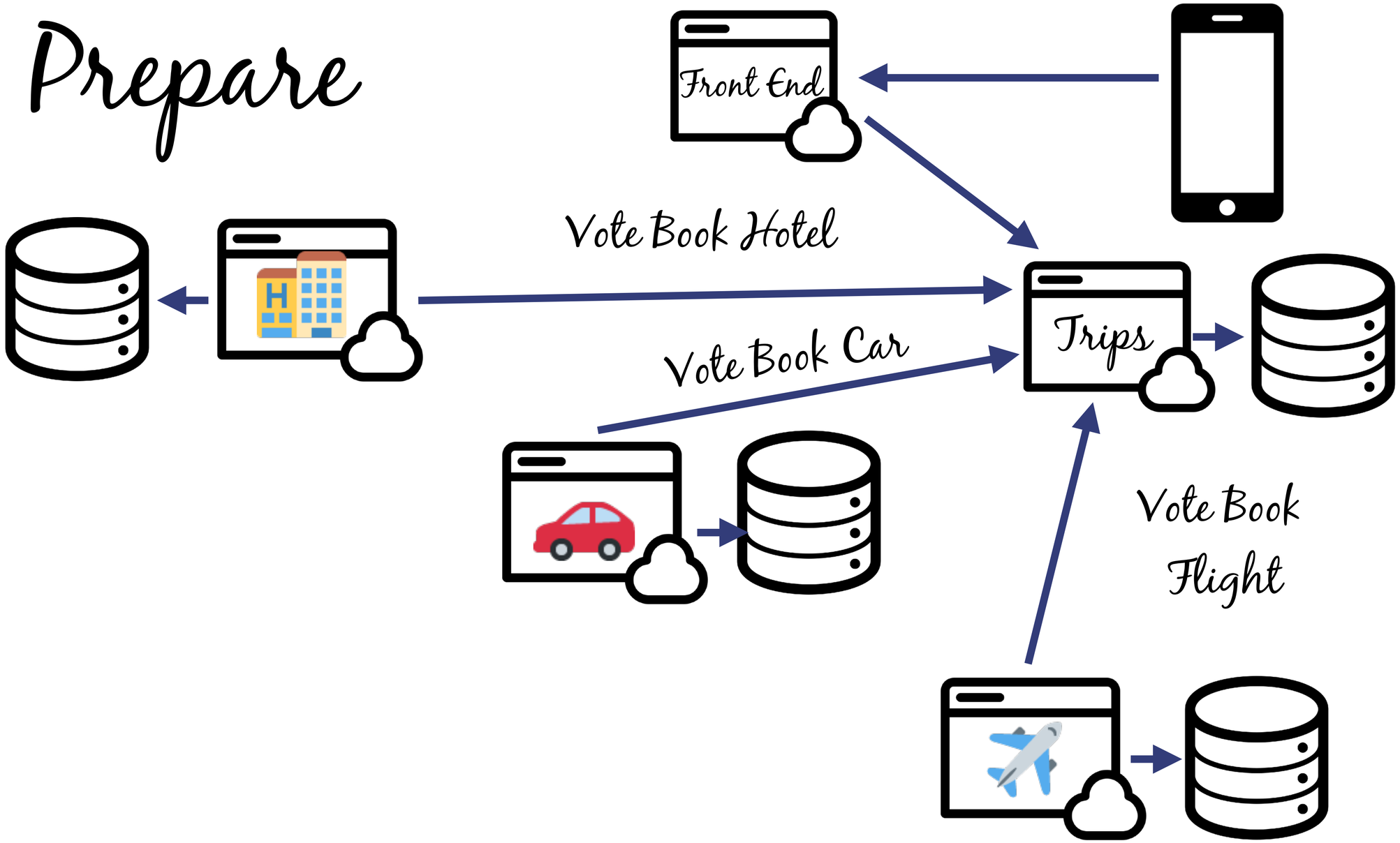
Two Phase Commit

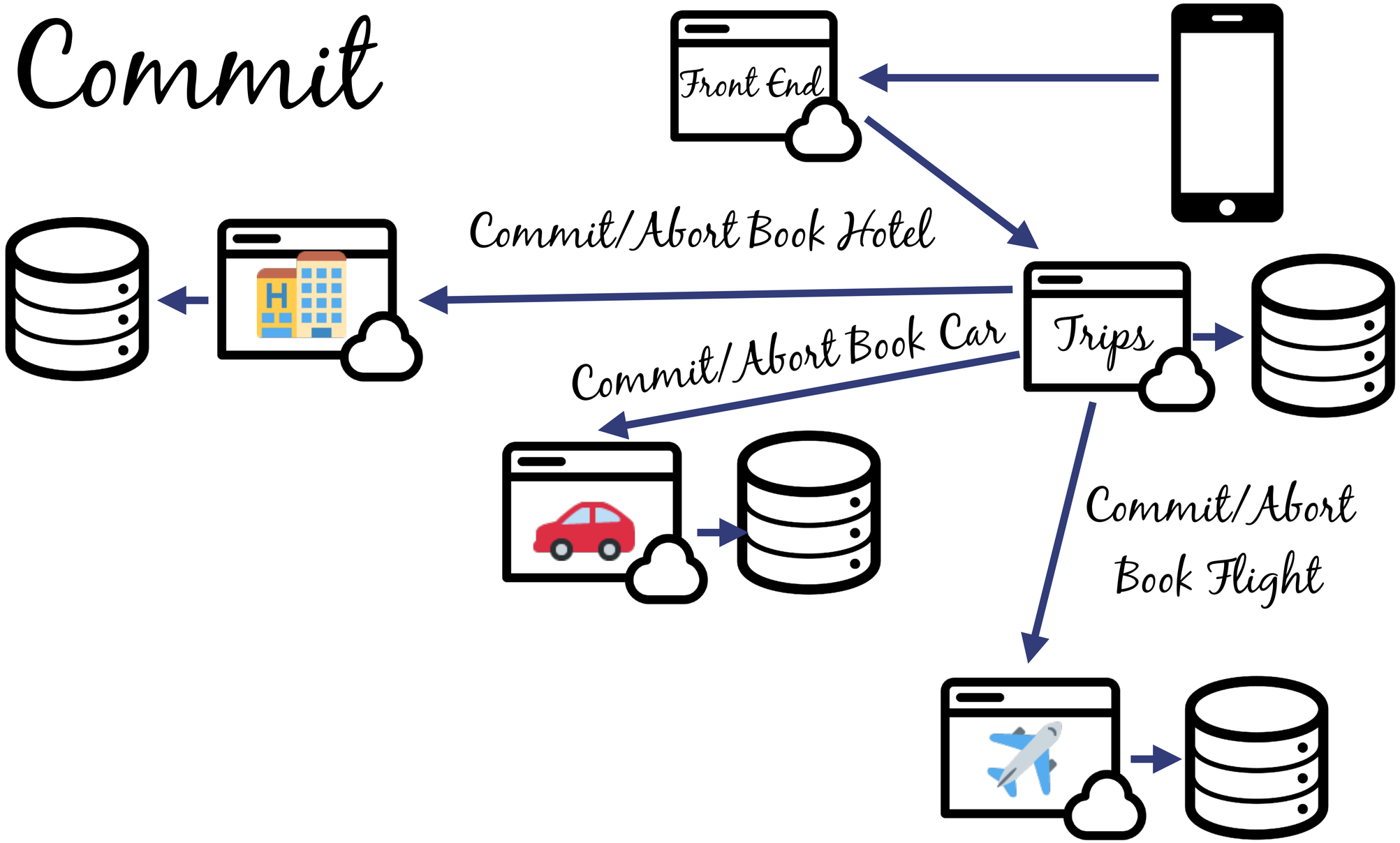
2PC: Prepare


Front End
Propose Book Hotel
Trips
Propose Book Car
Propose Book Flight

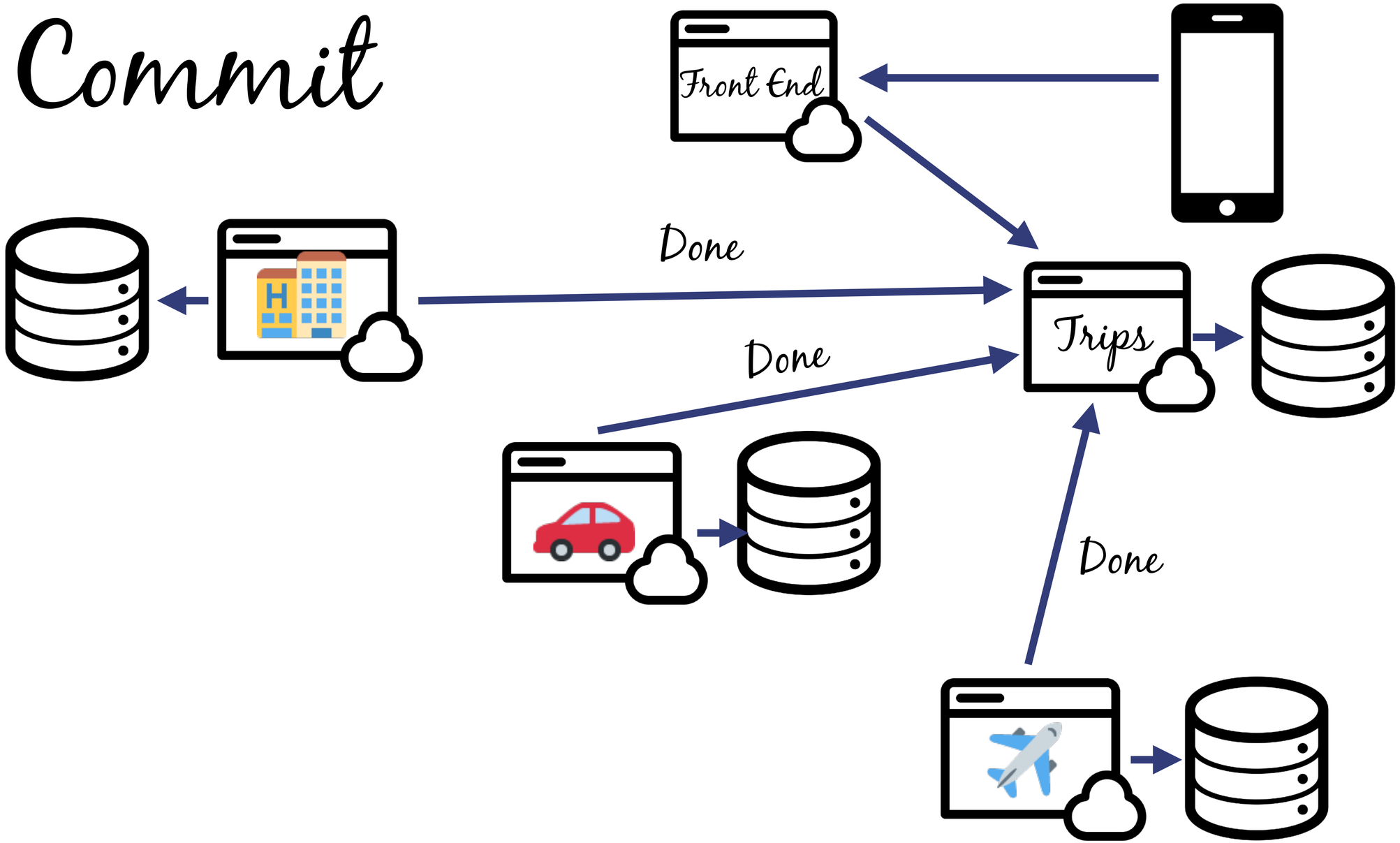
2PC: Prepare


Front End
Vote Book Hotel
Trips
Vote Book Car
Vote Book
Flight

2PC: Commit


Front End
Commit/Abort Book Hotel
Trips
Commit/Abort Book Car
Commit/Abort
Book Flight

2PC: Commit



2PC: Doesn't Scale

- O (N^2) Messages in the worst case
- Coordinator is a Single Point of Failure
- Reduced Throughput

Distributed Sagas

A Protocol for Coordinating Microservices

1987

SAGAS

Hector Garcia-Molina
Kenneth Salem

Department of Computer Science
Princeton University
Princeton, N J 08544

Abstract

Long lived transactions (LLTs) hold on to database resources for relatively long periods of time, significantly delaying the termination of shorter and more common transactions To alleviate these problems we propose the notion of a saga A LLT is a saga if it can be written as a sequence of transactions that can be interleaved with other transactions The database management system guarantees that either all the transactions in a saga are successfully completed or compensating transactions are run to amend a partial execution Both the concept of saga and its implementation are relatively simple, but they have the potential to improve performance significantly We analyze the various implementation issues related to sagas, including how they can be run on an existing system that does not directly support them We also discuss tech-

the majority of other transactions either because it accesses many database objects, it has lengthy computations, it pauses for inputs from the users, or a combination of these factors Examples of LLTs are transactions to produce monthly account statements at a bank, transactions to process claims at an insurance company, and transactions to collect statistics over an entire database [Gray81a]

In most cases, LLTs present serious performance problems Since they are transactions, the system must execute them as atomic actions, thus preserving the consistency of the database [Date81a, Ullm82a] To make a transaction atomic, the system usually locks the objects accessed by the transaction until it commits, and this typically occurs at the end of the transaction As a consequence, other transactions wishing to access the LLT's objects suffer a

1987

SAGAS

Hector Garcia-Molina
Kenneth Salem

Department of Computer Science

"Sagas are Long Lived Transactions (in a single relational Database)"

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1987

SAGAS

Hector Garcia-Molina
Kenneth Salem

"A Saga is a Long Lived Transaction that can be written as a sequence of transactions that can be interleaved.

All transactions in the sequence complete successfully or compensating transactions are ran to amend a partial execution."

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Distributed Sagas

A Protocol for Coordinating Microservices

A Distributed Saga is a Collection of Requests

 Book Hotel  Book Car  Book Flight  Charge Money

A Distributed Saga is a Collection of Requests

 Book Hotel  Book Car  Book Flight  Charge Money

and Compensating Requests

 Cancel Hotel  Cancel Car  Cancel Flight  Refund Money

A Distributed Saga is a Collection of Requests

 Book Hotel  Book Car  Book Flight  Charge Money

and Compensating Requests

 Cancel Hotel  Cancel Car  Cancel Flight  Refund Money

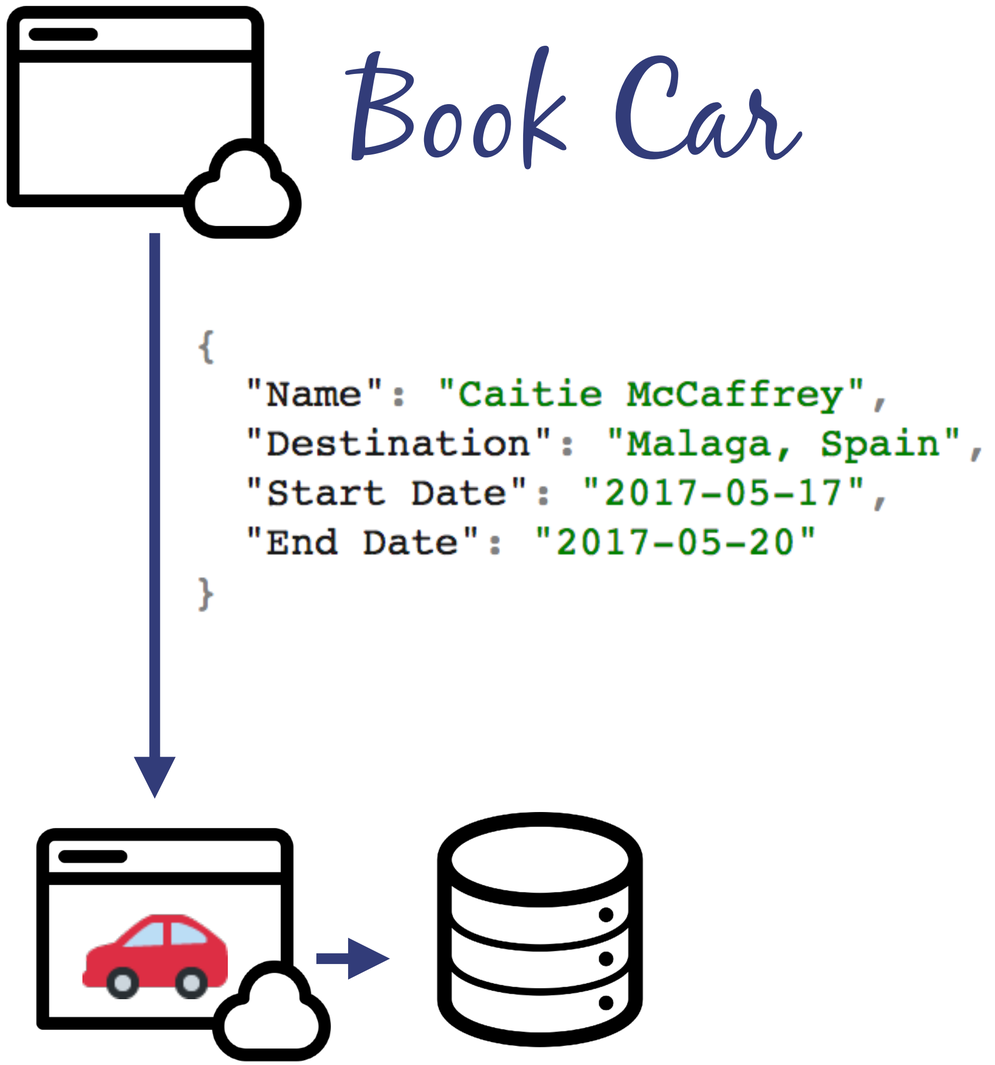
that represent a single business level action

Distributed Saga

Requests

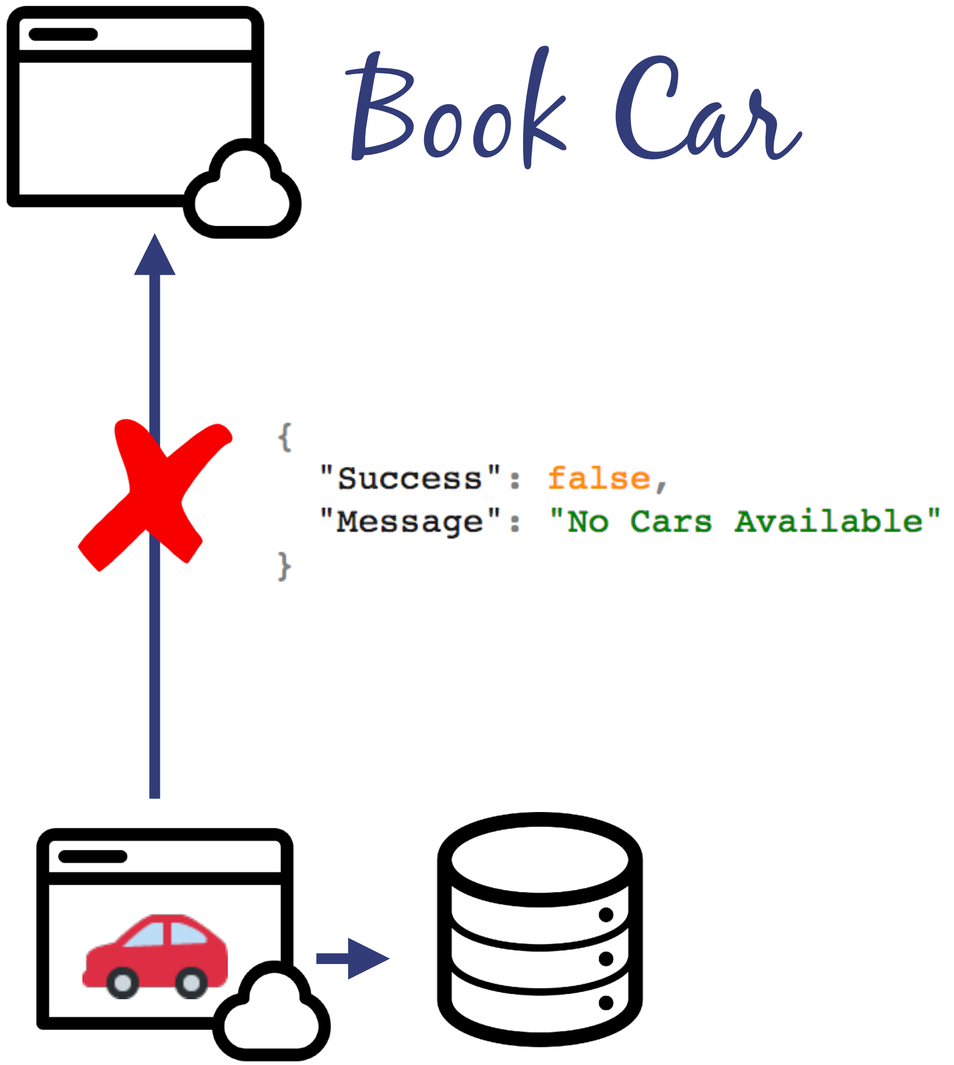
Requests

Can Abort



Requests

Can Abort



Requests

Must Be Idempotent


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20"
}
```

Requests

Must Be Idempotent


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20"
}
```

Requests

Must Be Idempotent


```
{
  "Success": "true",
  "Confirmation Number": "ABC456"
}
```

Requests

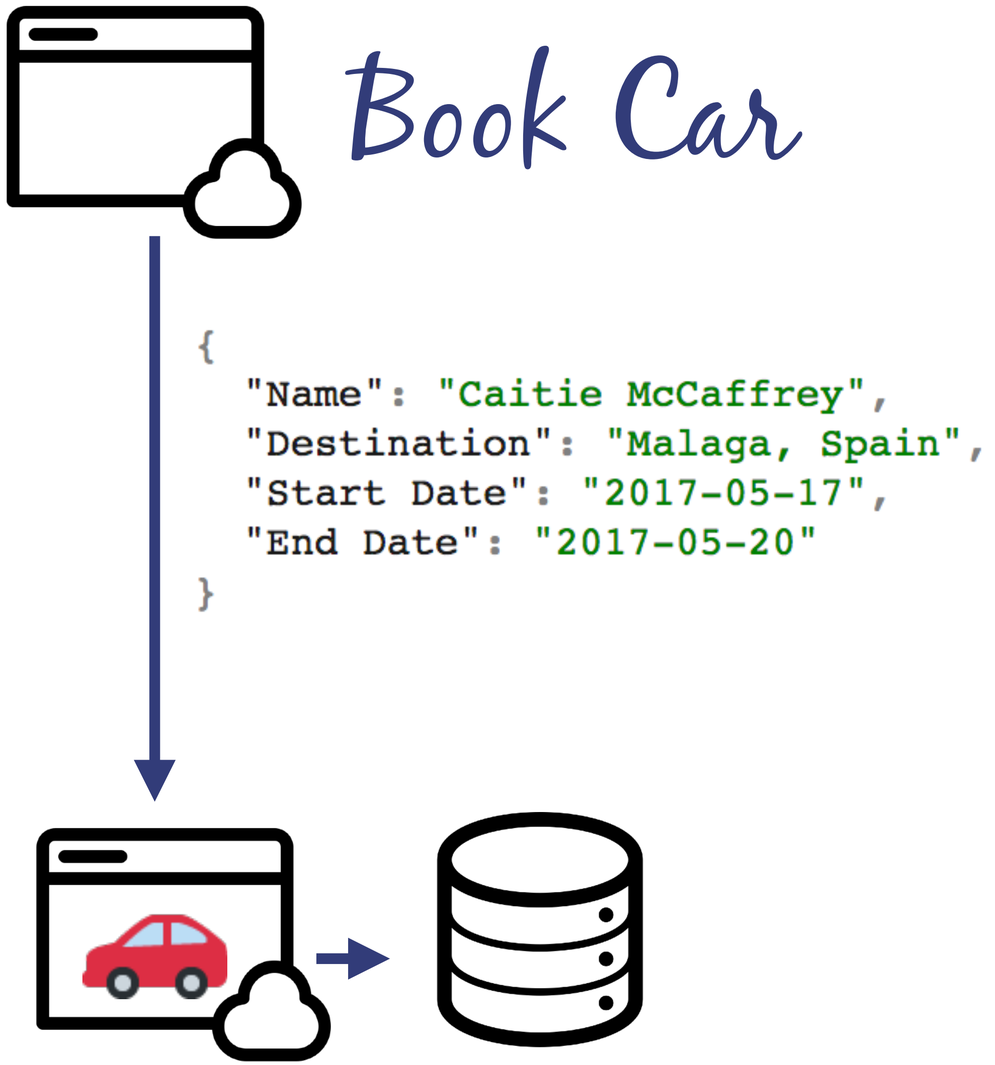
Must Be Idempotent

```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20"
}
```


```
{
  "Success": "true",
  "Confirmation Number": "ABC456"
}
```

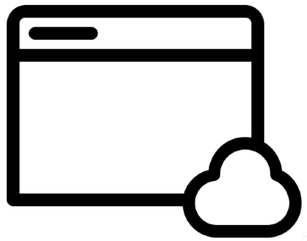
Requests

Must Be Idempotent



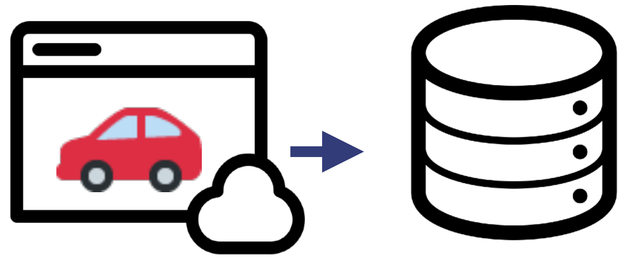
Requests

Must Be Idempotent



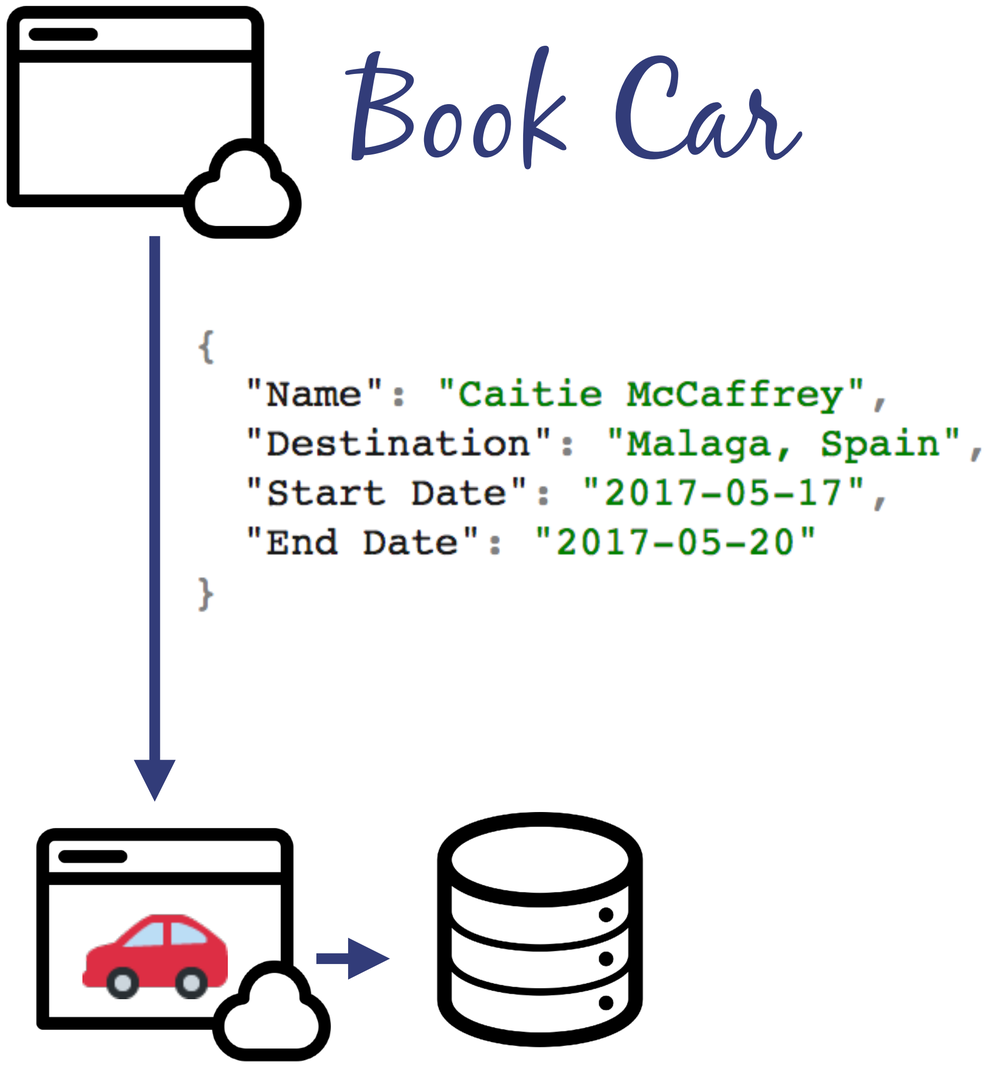
Book Car

Timeout



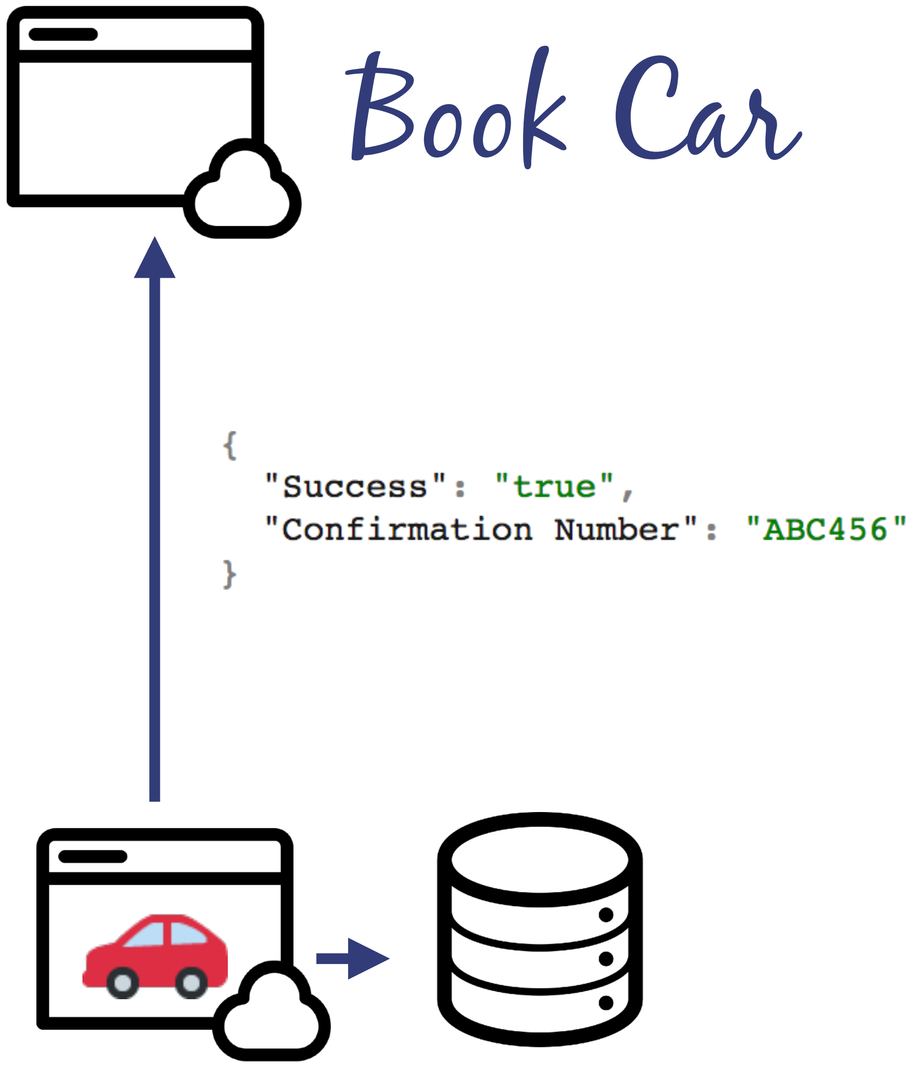
Requests

Must Be Idempotent



Requests

Must Be Idempotent



Distributed Saga

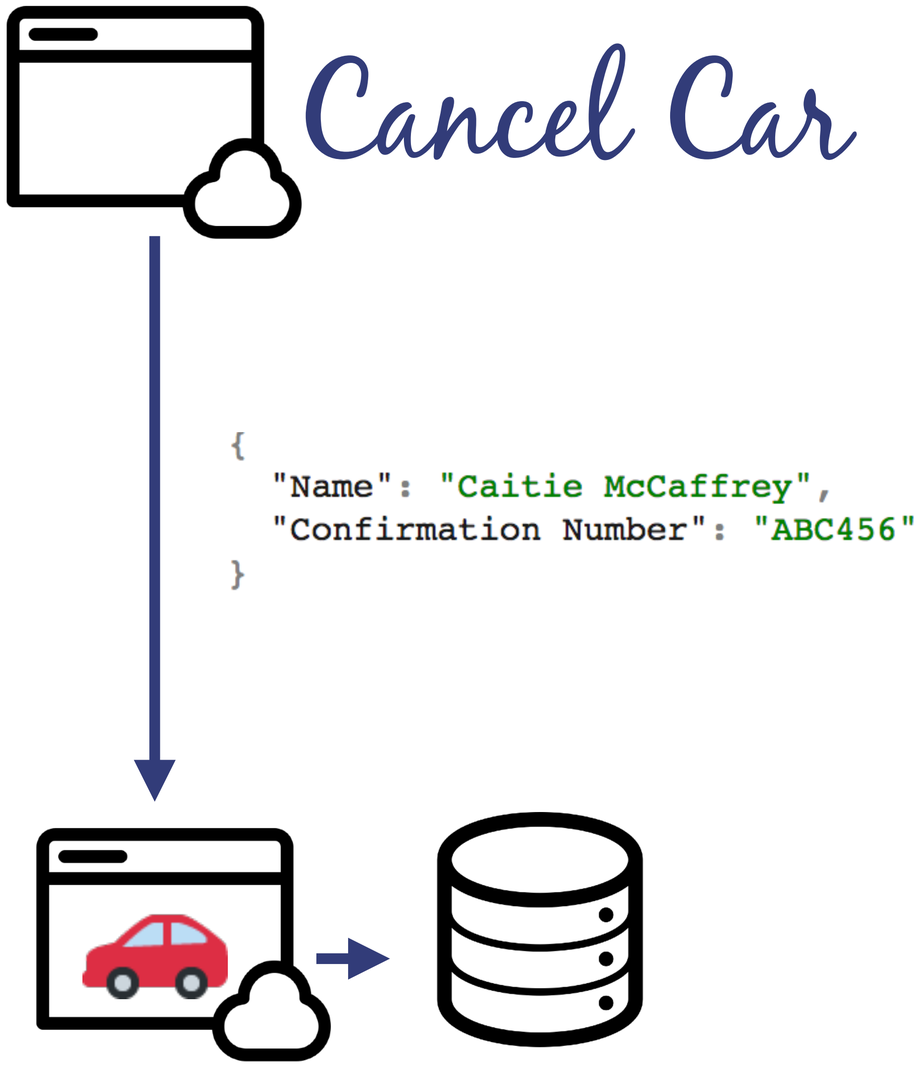
Compensating Requests

Compensating Requests

Semantically undoes the effect of a request

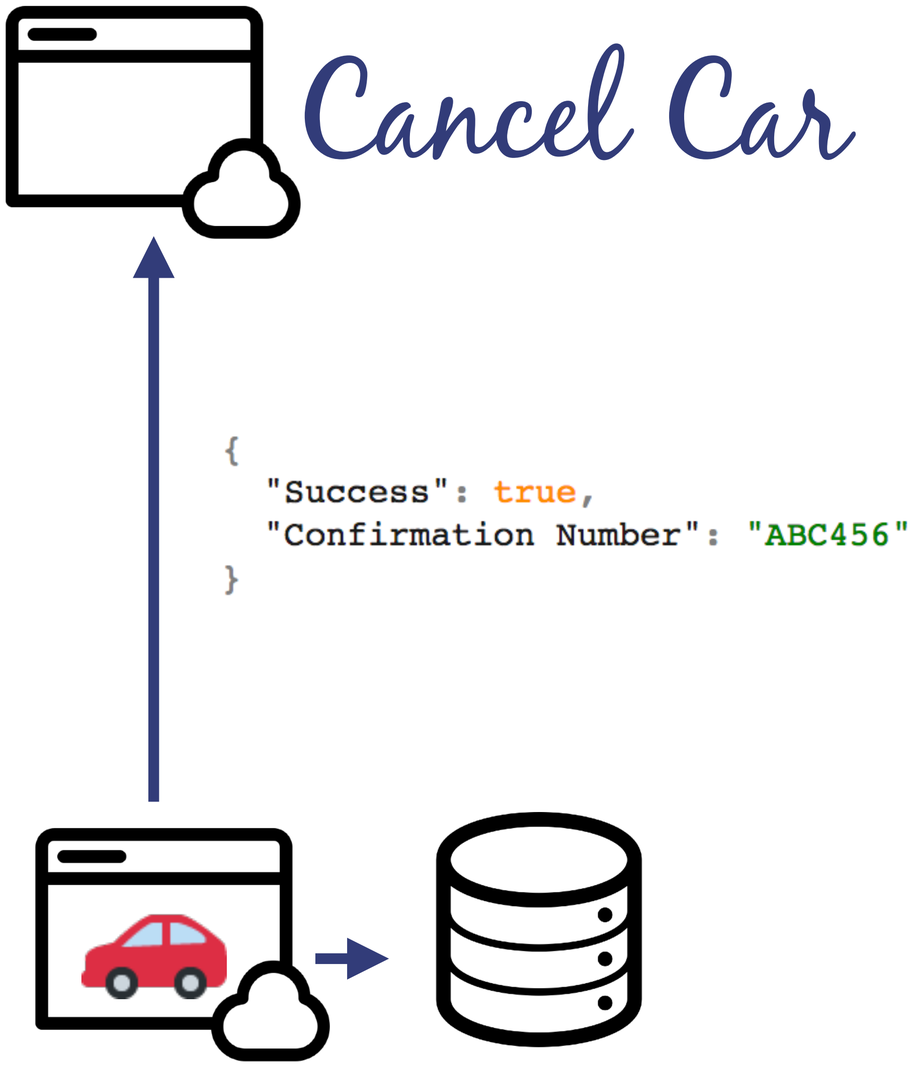
Compensating Requests

Cannot Abort



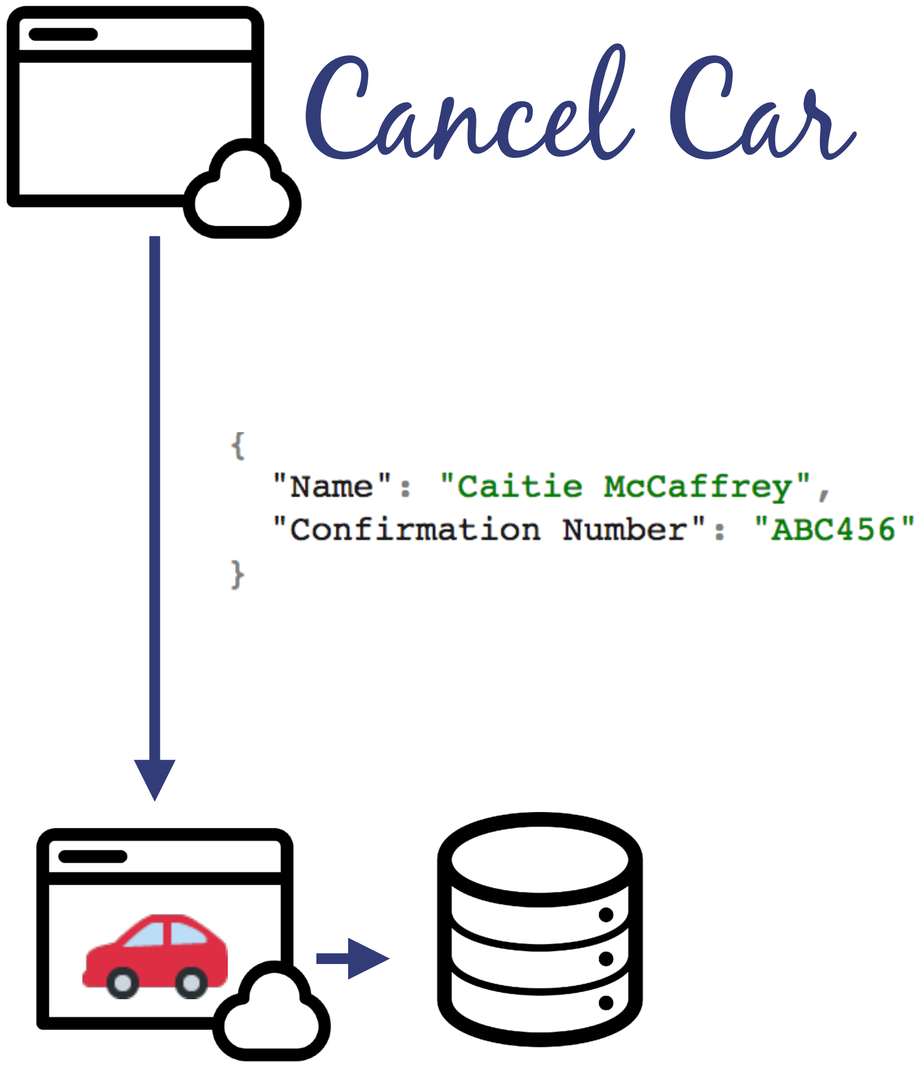
Compensating Requests

Can Not Abort



Compensating Requests

Must Be Idempotent



Compensating Requests

Must Be Commutative with Requests

 Book Car

 Cancel Car

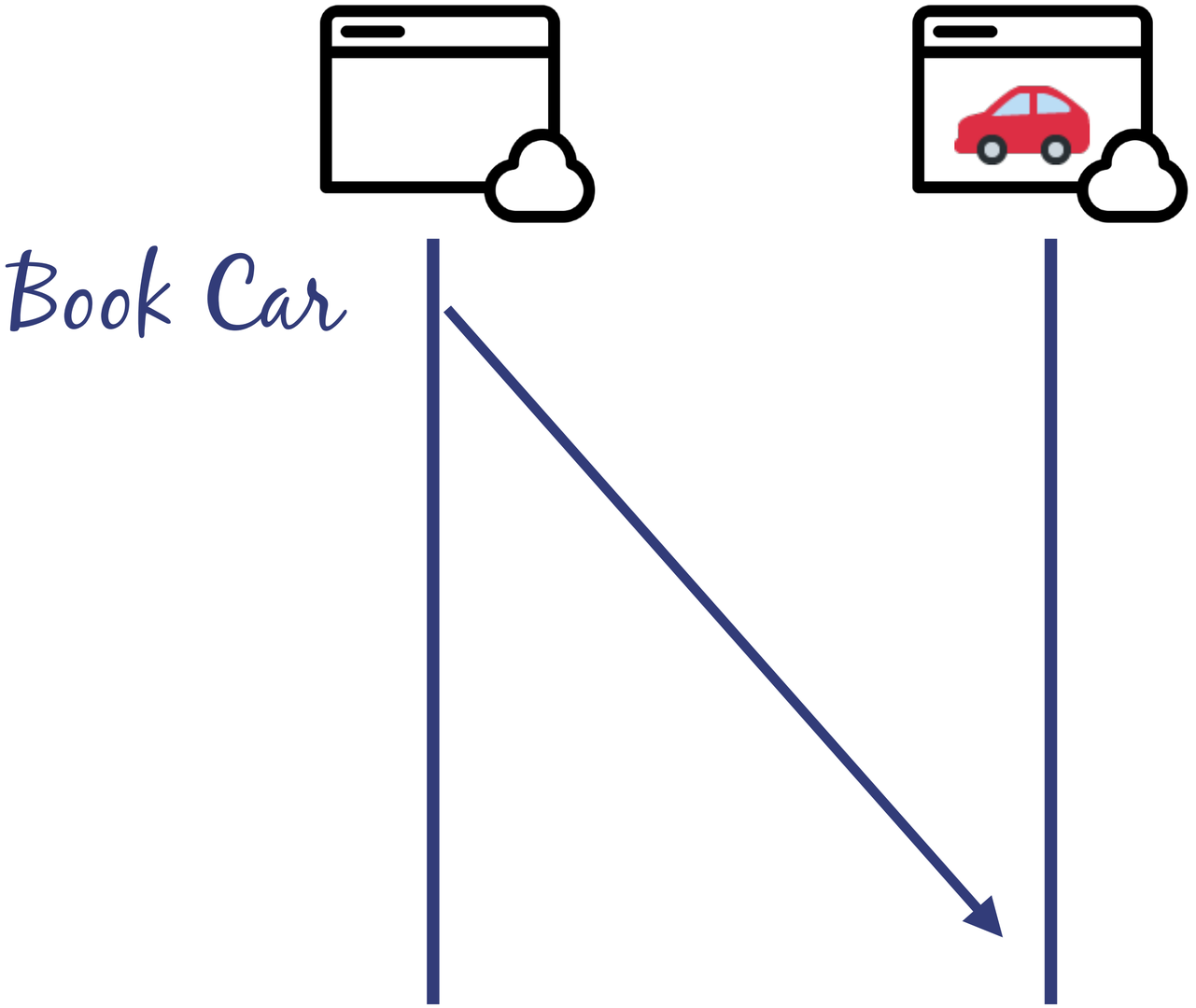
is the same as

 Cancel Car

 Book Car

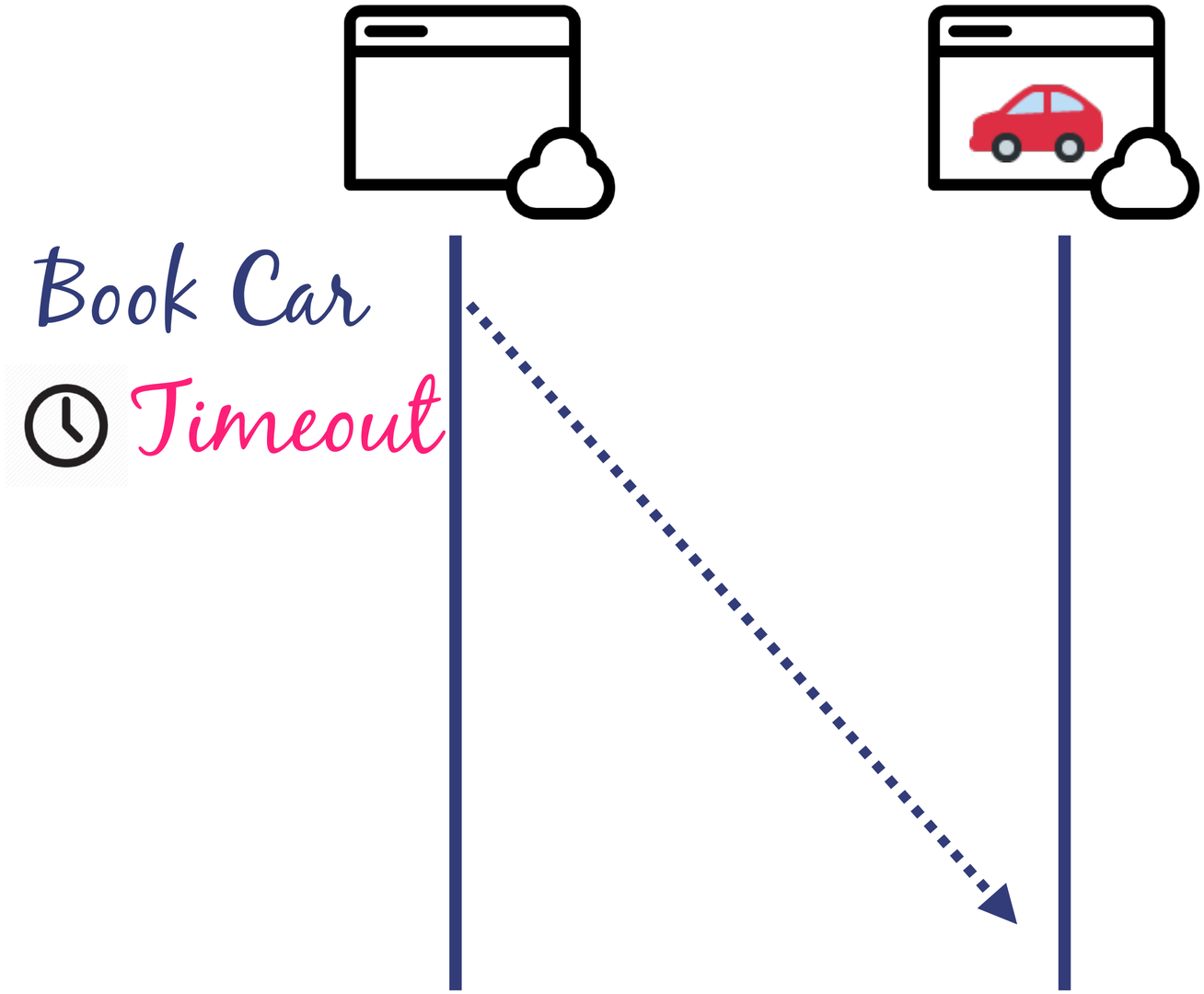
Compensating Requests

Must Be Commutative with Requests



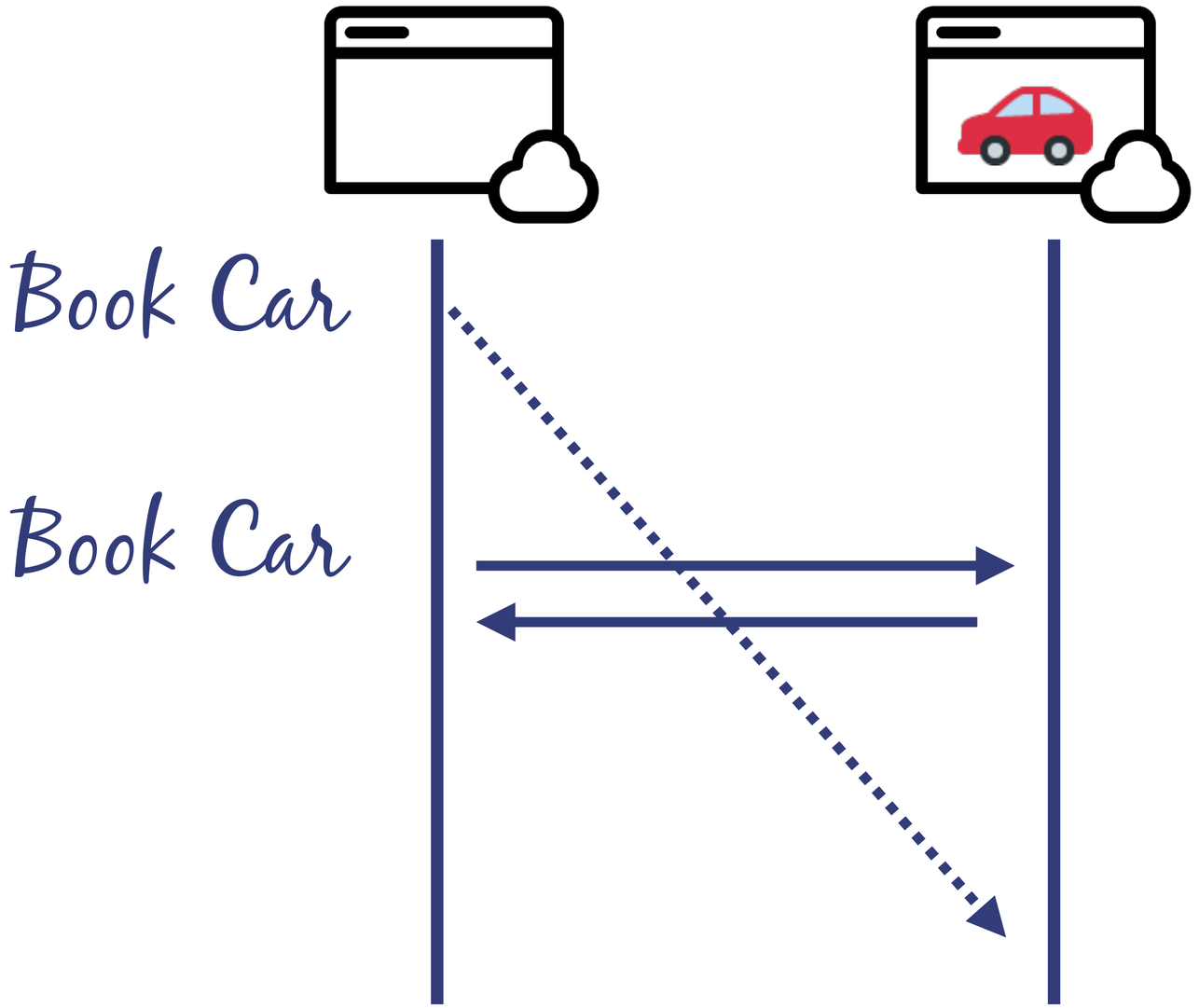
Compensating Requests

Must Be Commutative with Requests



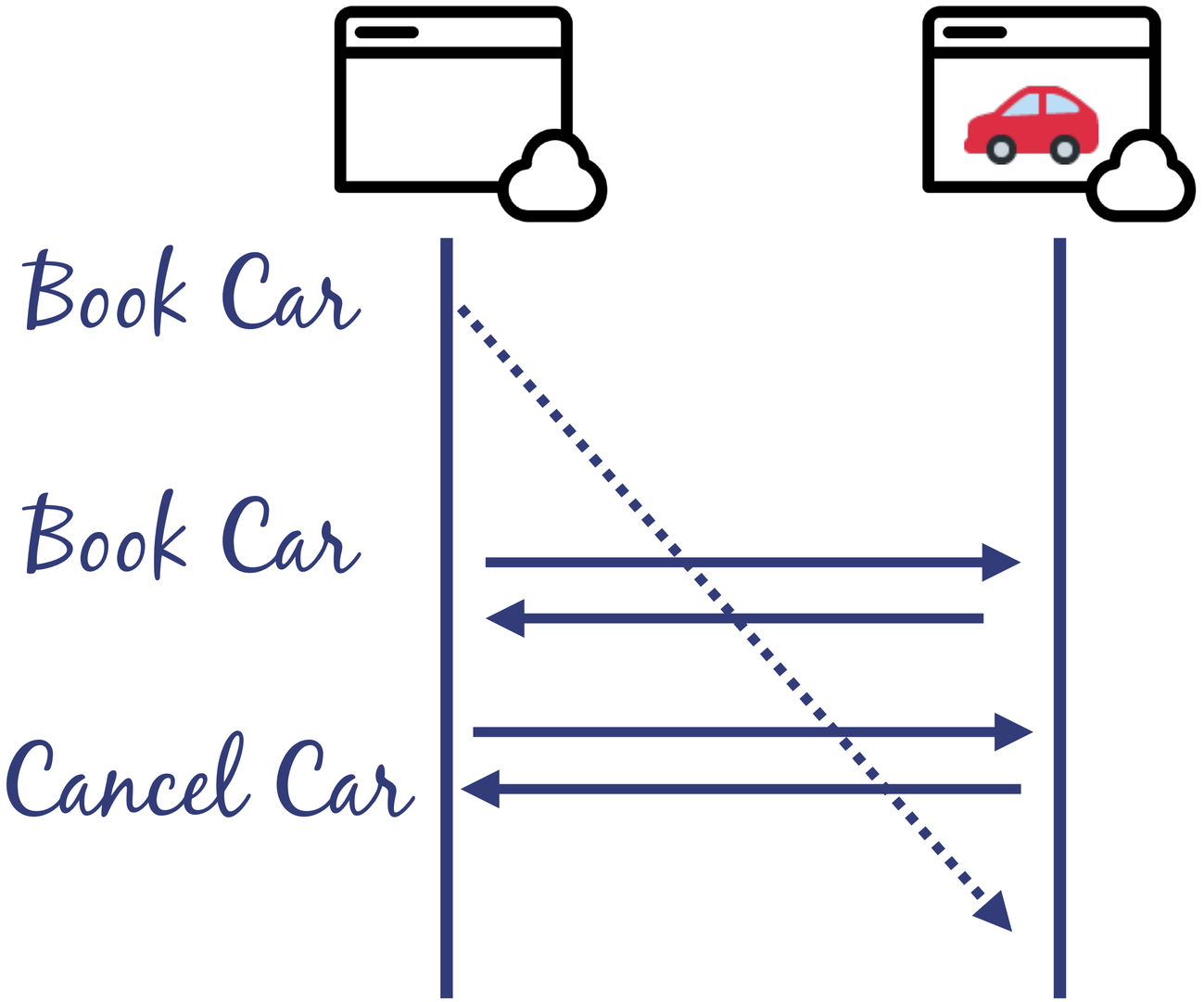
Compensating Requests

Must Be Commutative with Requests



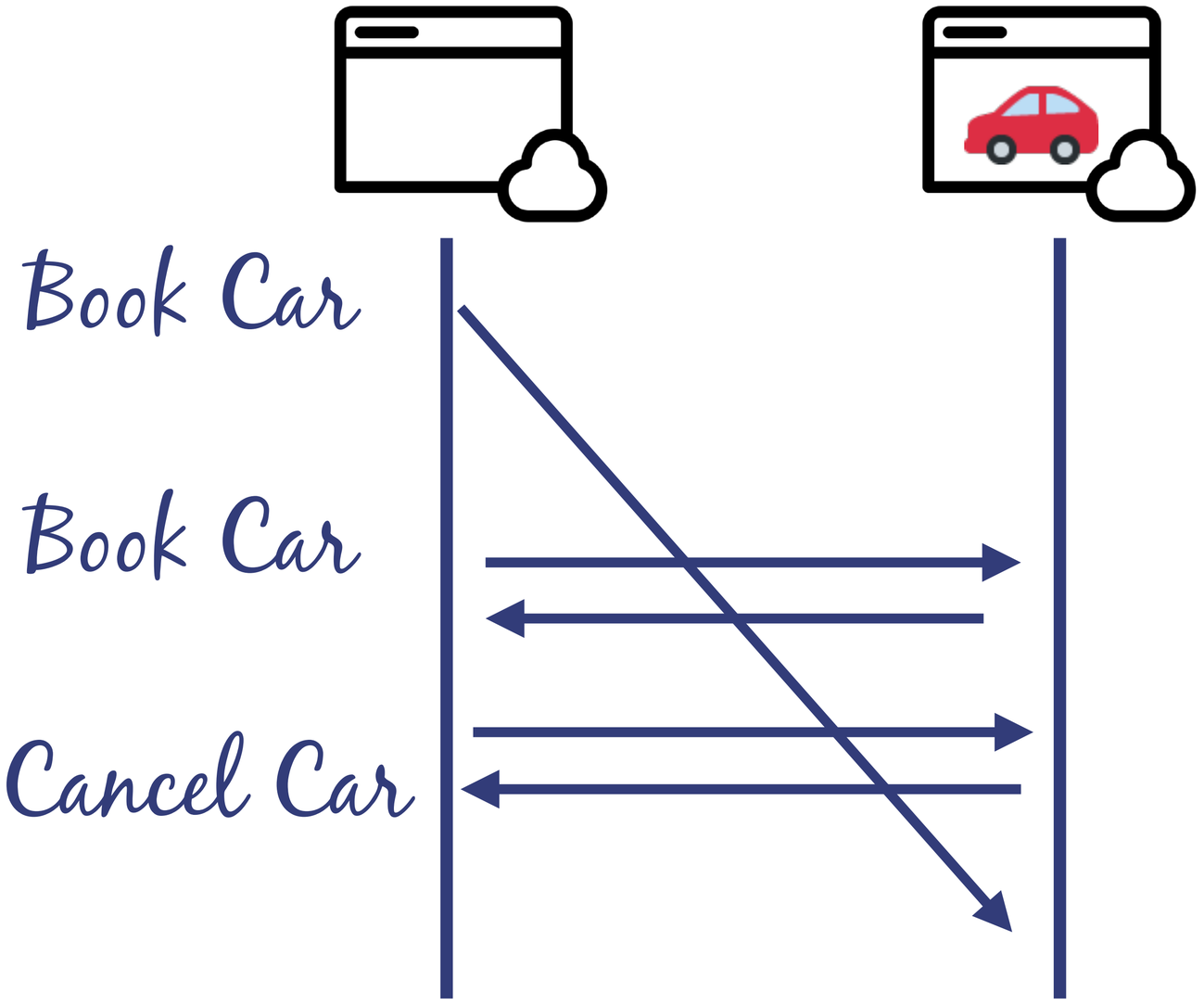
Compensating Requests

Must Be Commutative with Requests



Compensating Requests

Must Be Commutative with Requests



Requests

Idempotent

Can Abort

Compensating Requests

Idempotent

Commutative

Can Not Abort

Distributed Saga Guarantee

All requests were completed successfully

 Book Hotel  Book Car  Book Flight  Charge Money

Distributed Saga Guarantee

All requests were completed successfully

 Book Hotel  Book Car  Book Flight  Charge Money

Or a subset of requests and the corresponding compensating requests were executed

 Book Hotel  Book Car  Cancel Hotel  Cancel Car

Distributed Saga Guarantee

No Atomicity

No Isolation

Distributed Saga Guarantee

No Atomicity

No Isolation

Visible before Saga Completes

Book Hotel

Book Car

Distributed Saga Guarantee

All requests were completed successfully

 Book Hotel  Book Car  Book Flight  Charge Money

Or a subset of requests and the corresponding compensating requests were executed

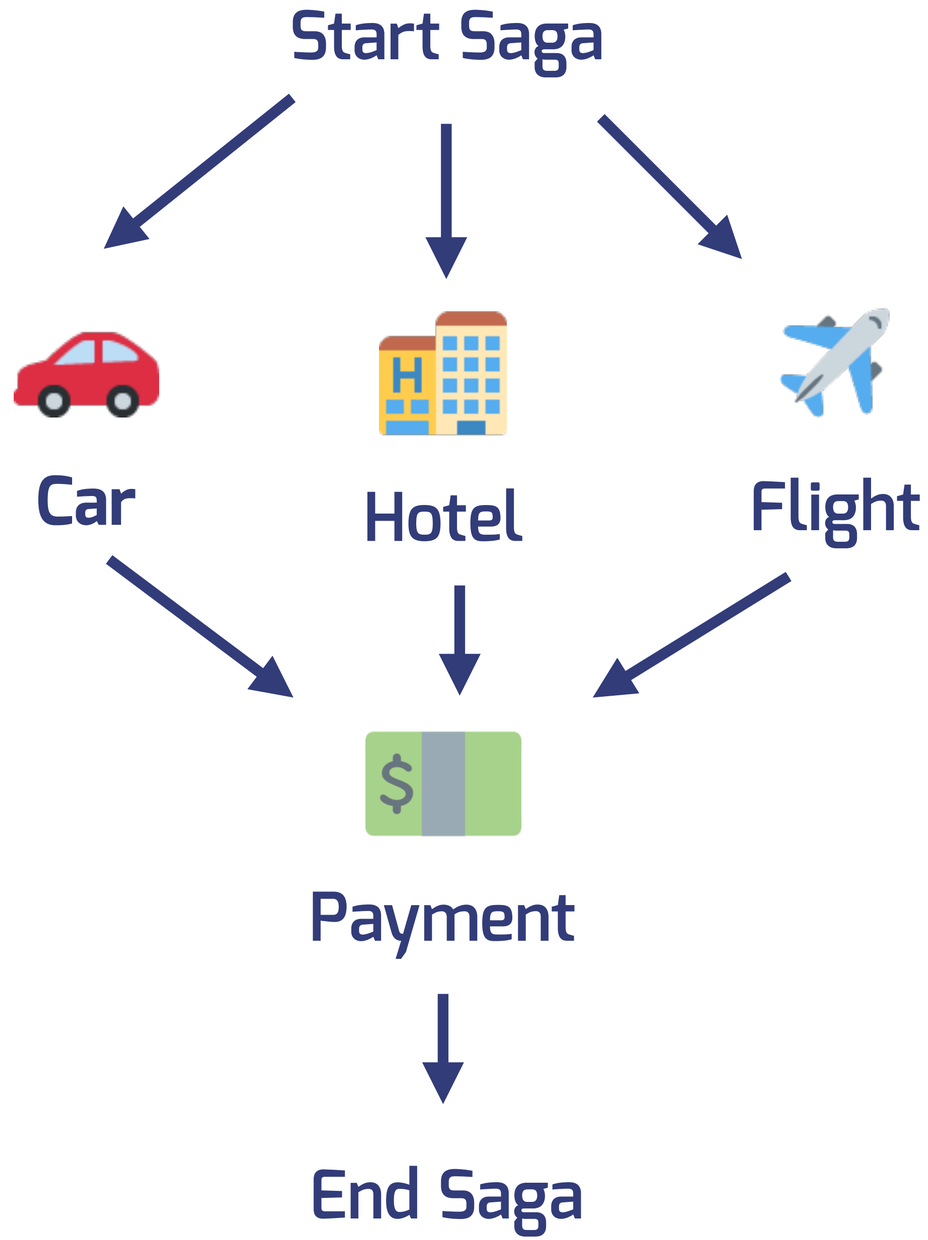
 Book Hotel  Book Car  Cancel Hotel  Cancel Car

defining a

Distributed Saga

Distributed Saga

Directed Acyclic Graph



Distributed Saga **Vertex**

Name: Hotel

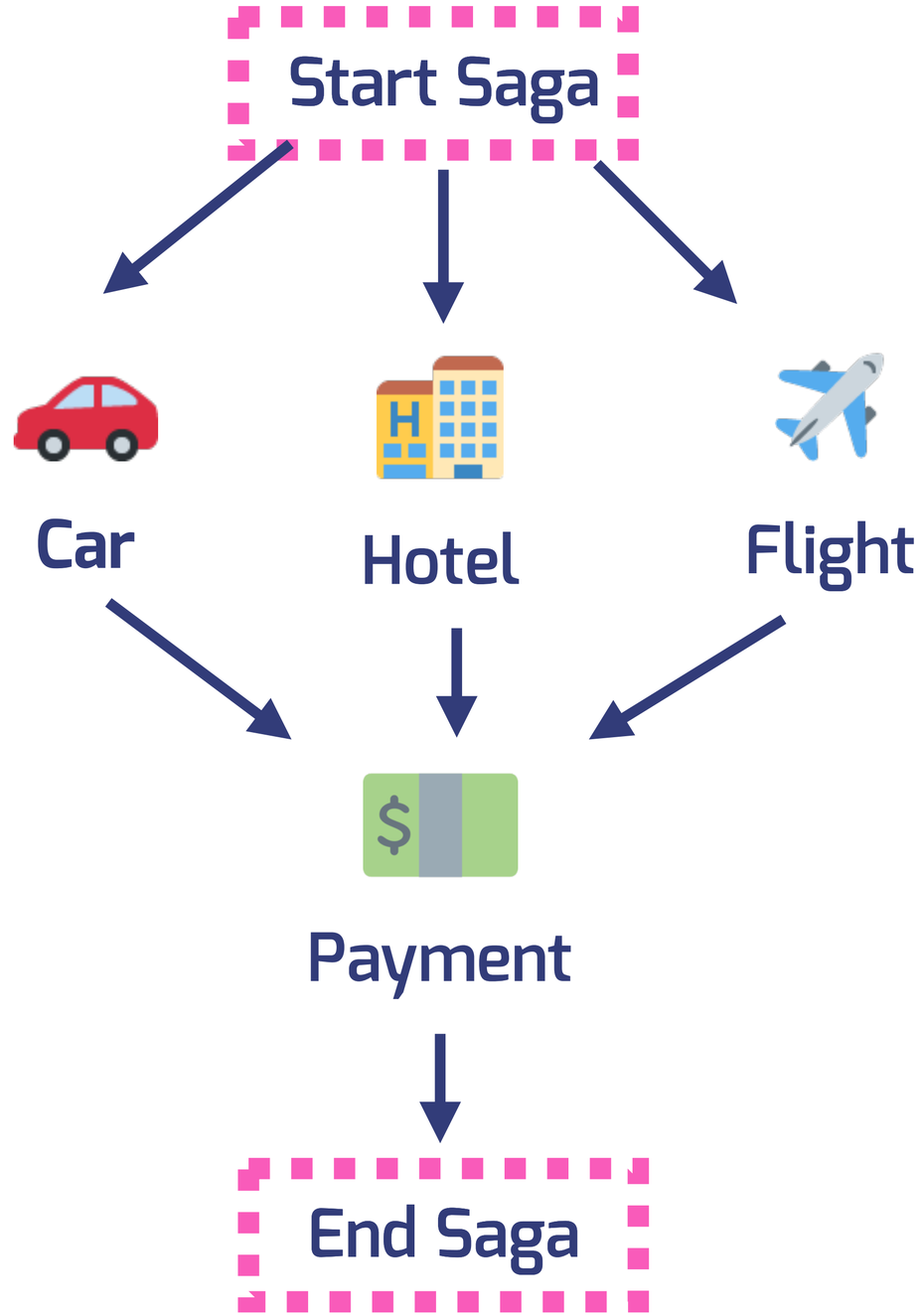
Request: Book Hotel

Compensating Request: Cancel Hotel

Status: Not Completed

Distributed Saga

Start & End Vertices

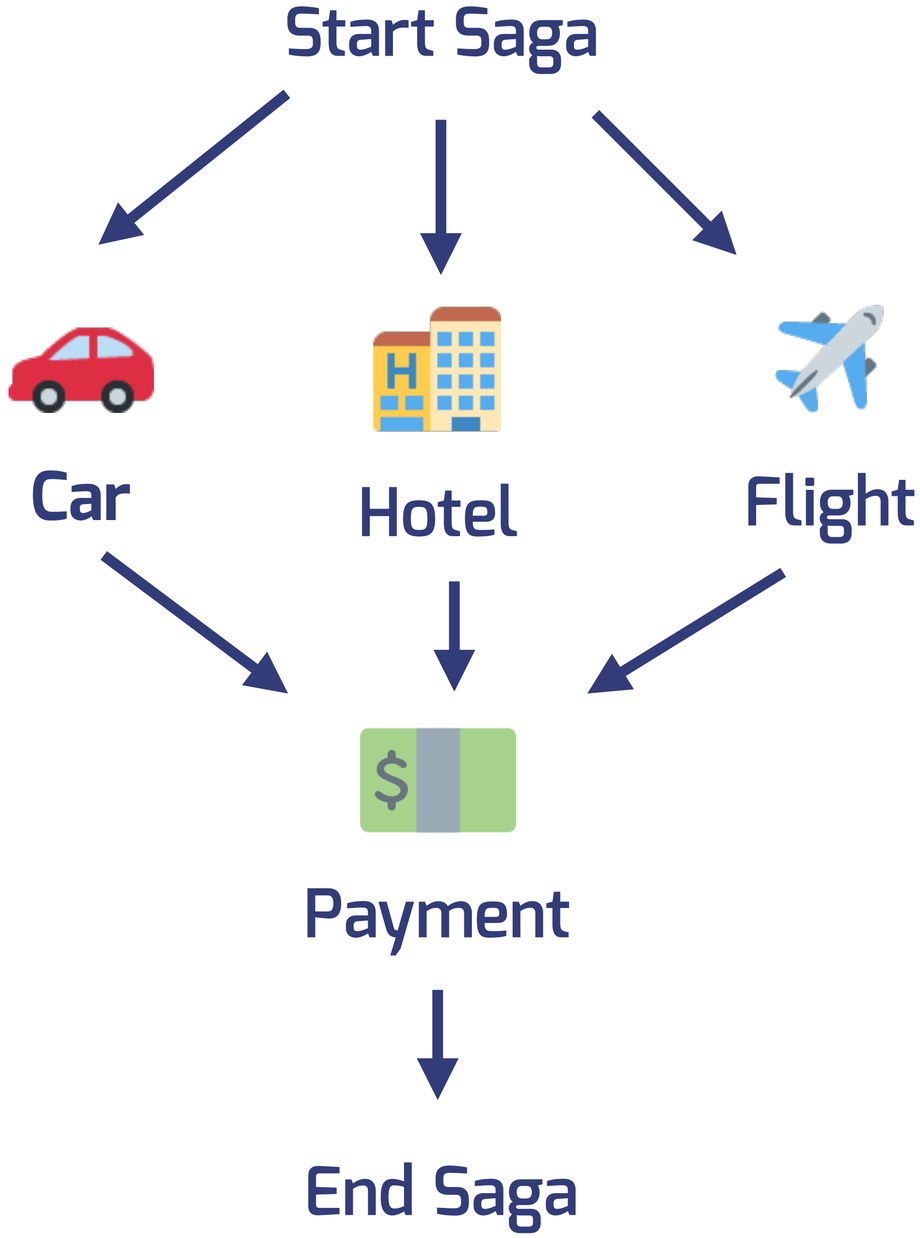


Distributed Saga Log

fault-tolerant & highly available

Saga Execution Coordinator

Saga Log



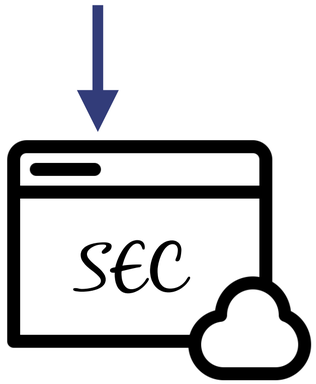
Executing a

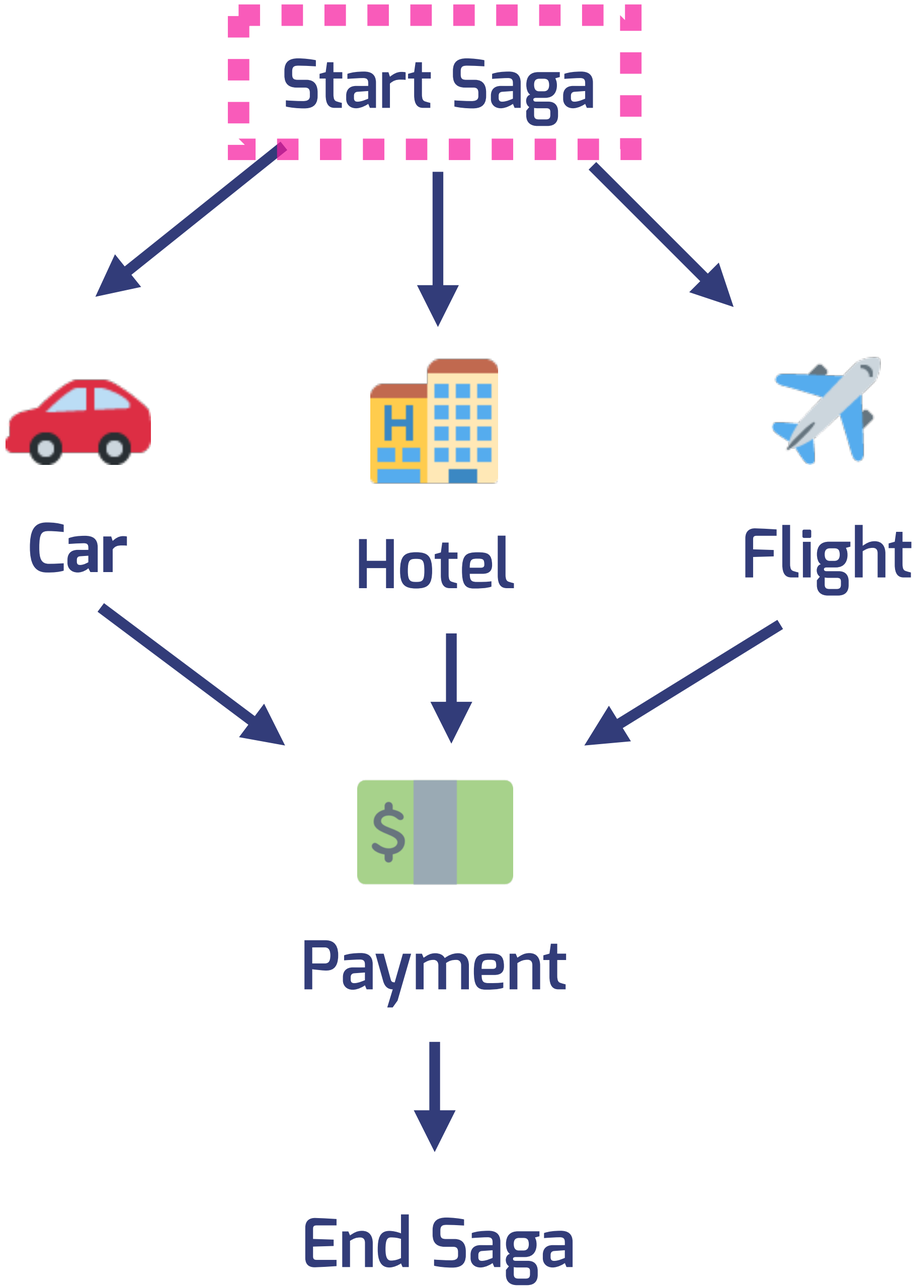
Distributed Saga

Saga Log

Book Trip Request


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6KQ==",
  "Price": "2500USD"
}
```

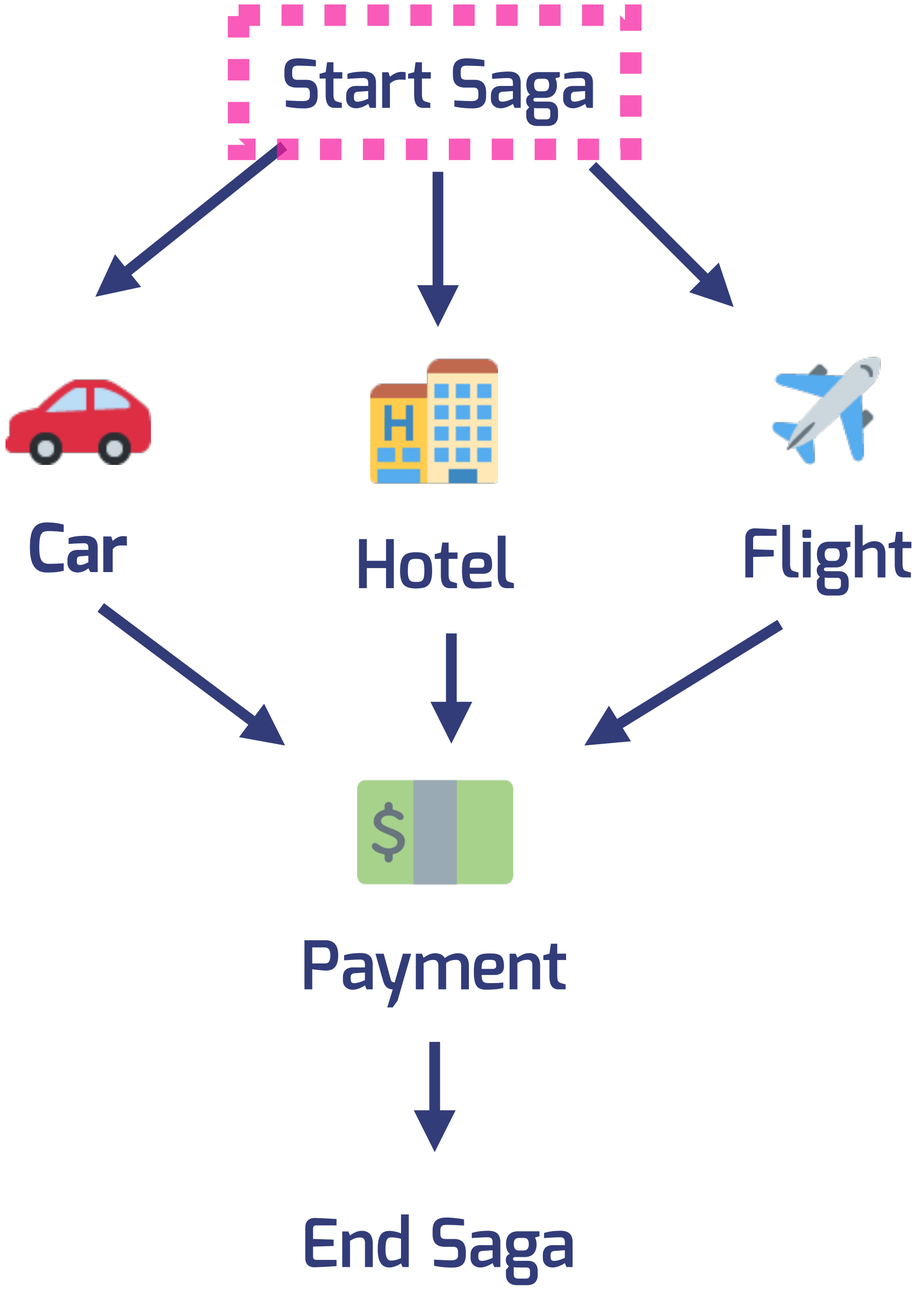


Saga Log

Book Trip Request


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6KQ==",
  "Price": "2500USD"
}
```


Start Saga



Saga Log

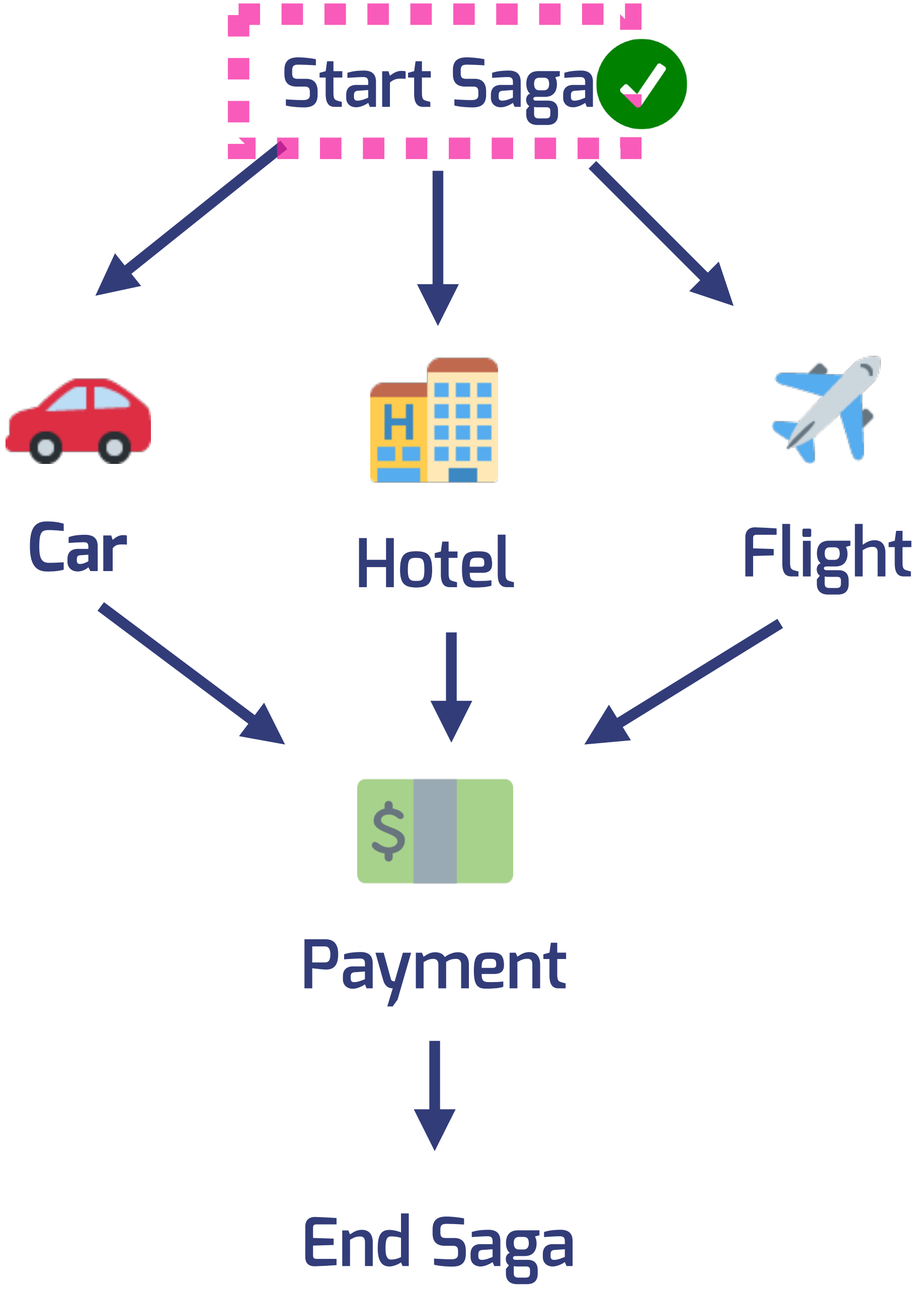
Start Saga

{
"Name": "Caitie McCaffrey",
"Destination": "Malaga, Spain",
"Start Date": "2017-05-17",
"End Date": "2017-05-20",
"Payment Token":
"Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6KQ=="
}

Book Trip Request

```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6KQ==",
  "Price": "2500USD"
}
```

Done

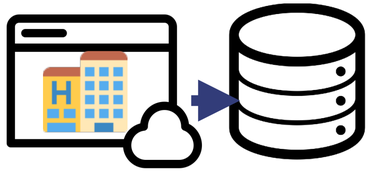


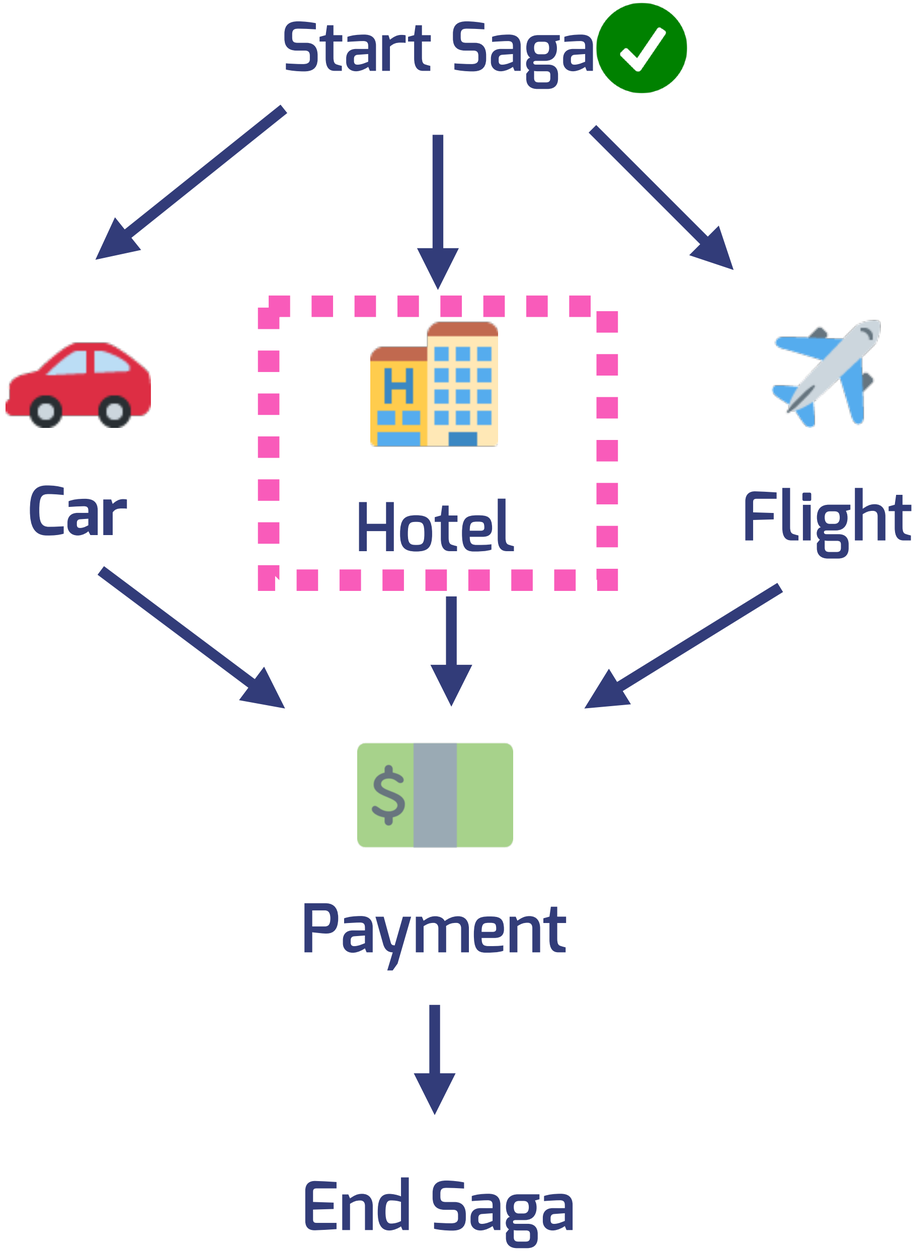
Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Q=="
}
```


Start Hotel





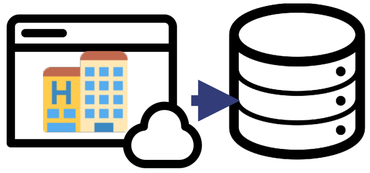
Saga Log

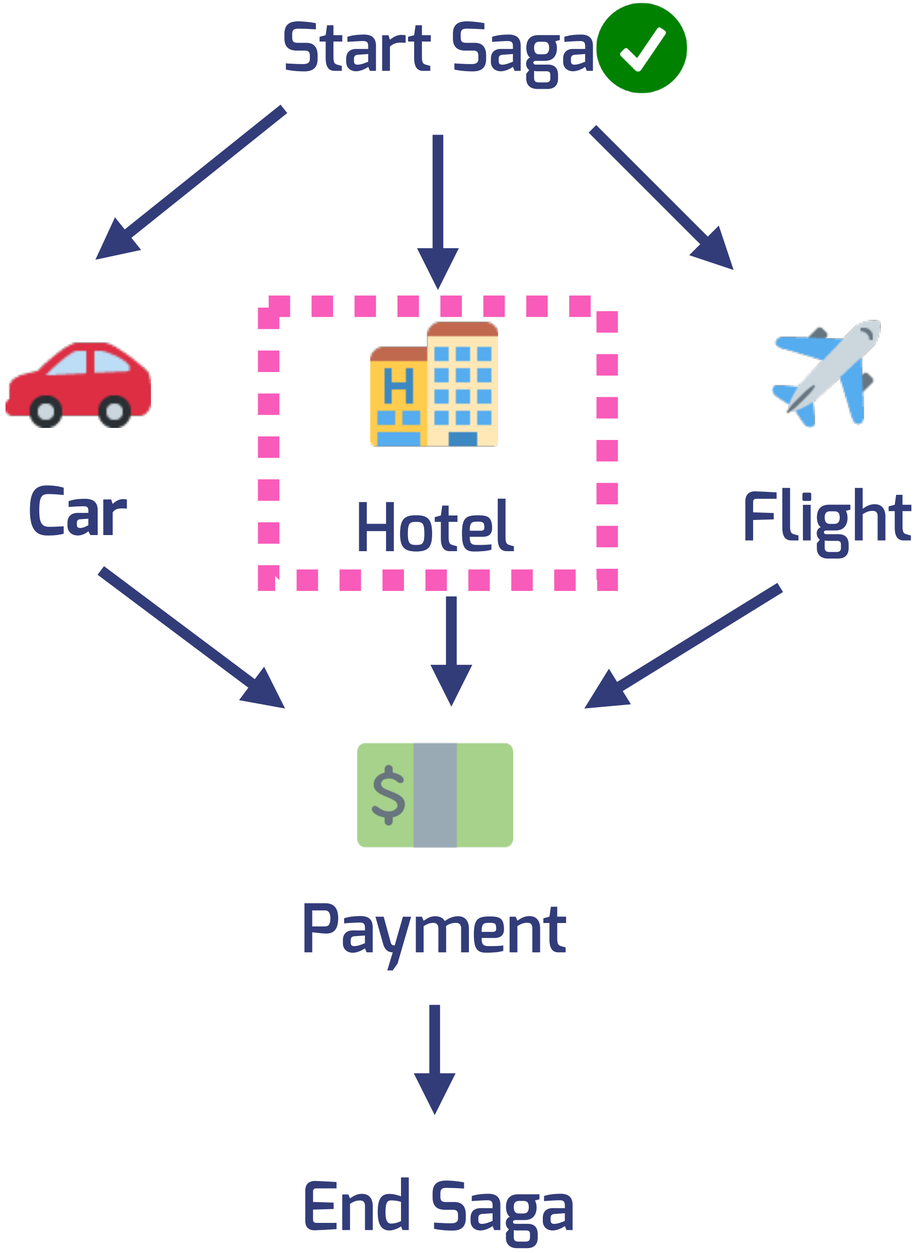
Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Q=="
}
```


Start Hotel

Done





Saga Log

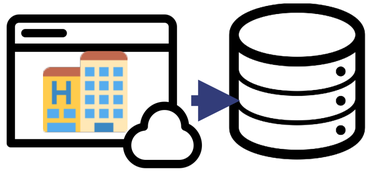
Start Saga

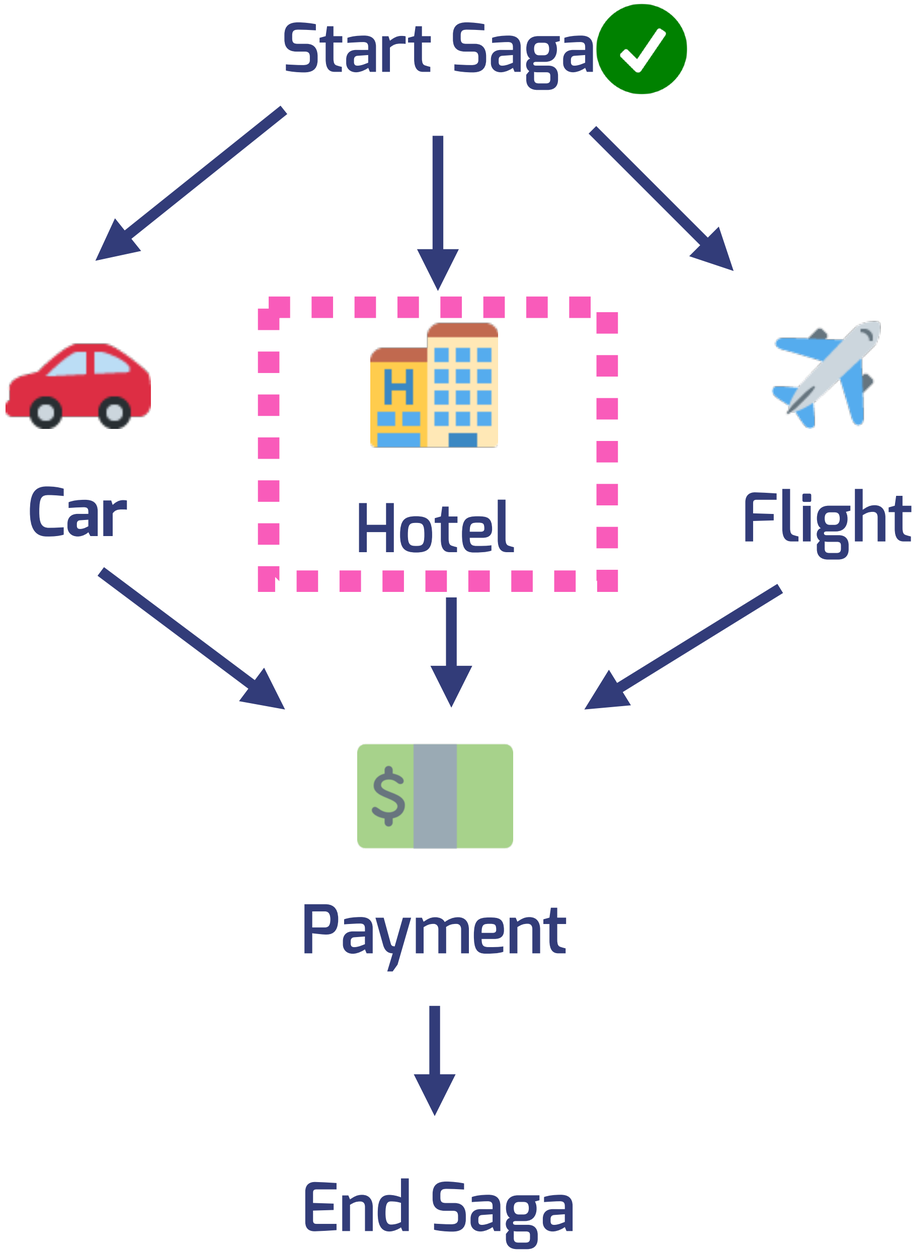

```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Kg=="
}
```


Start Hotel

Book Hotel Request


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20"
}
```



Saga Log

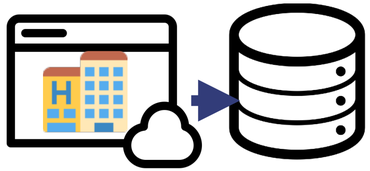
Start Saga

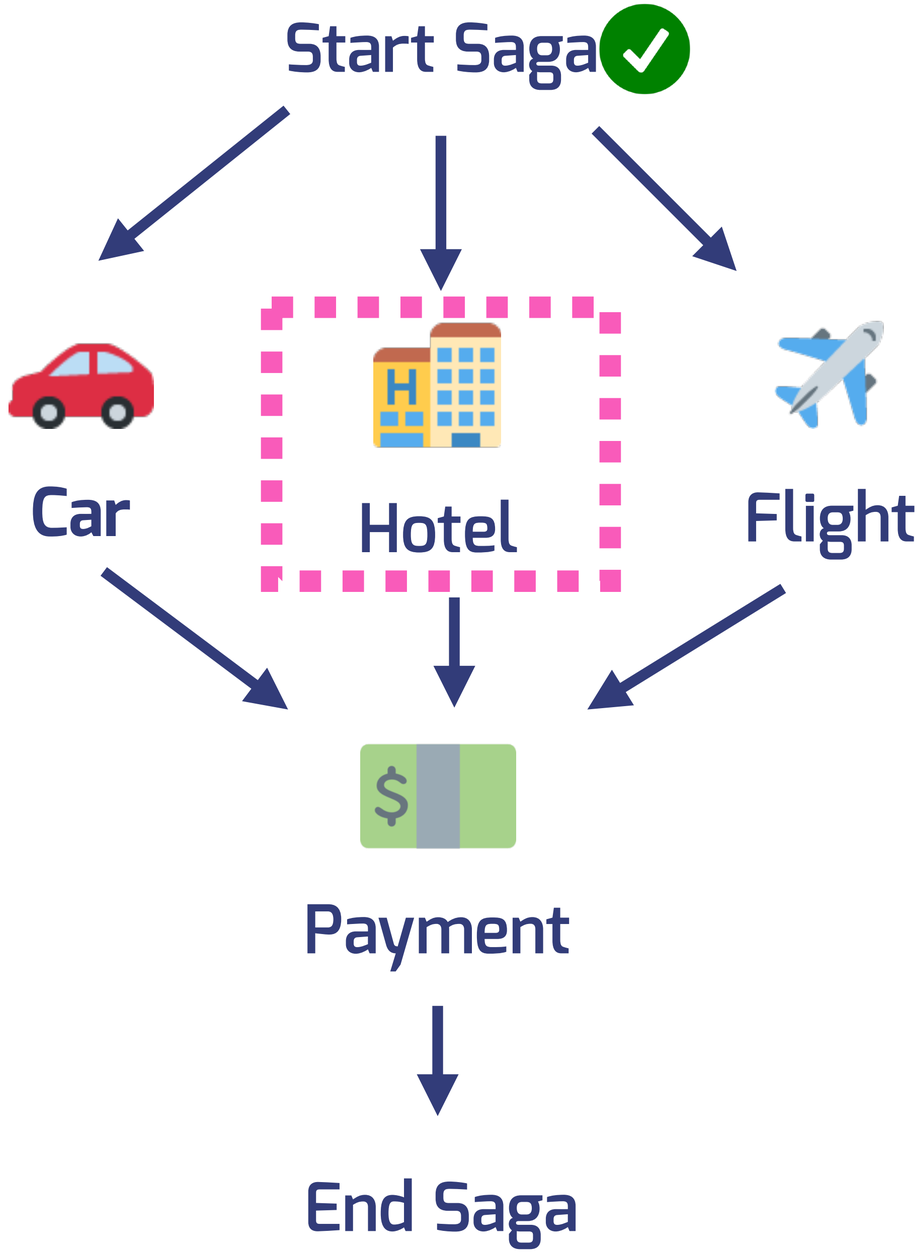

```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Kg=="
}
```


Start Hotel

Book Hotel Response


```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```



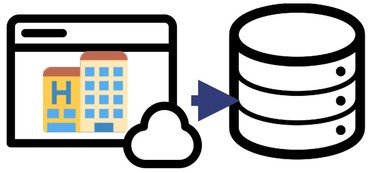
Saga Log

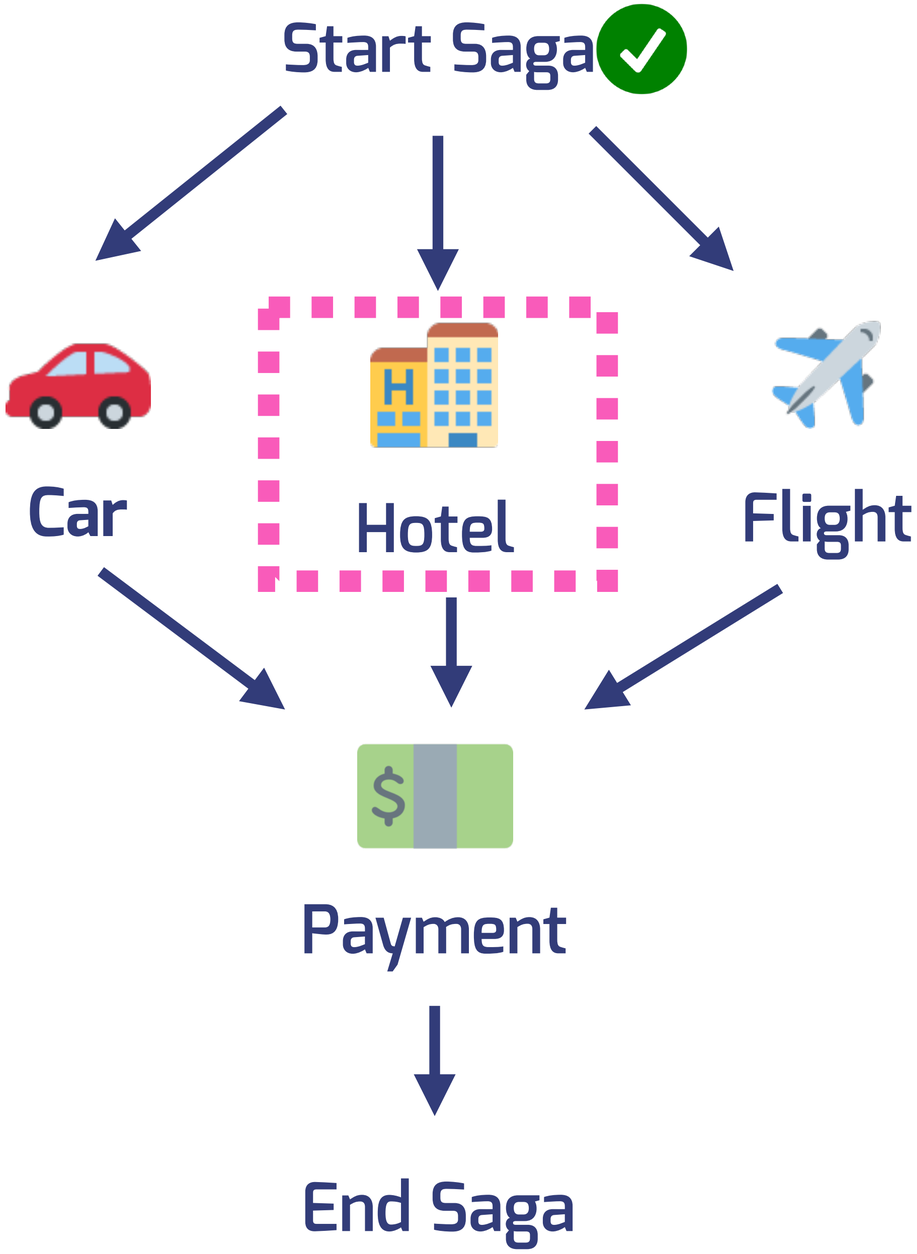
Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Kg=="
}
```


Start Hotel

End Hotel





Saga Log

Start Saga

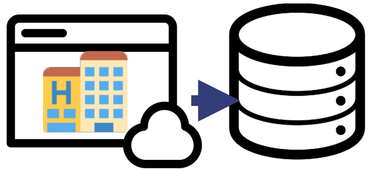

```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Kg=="
}
```

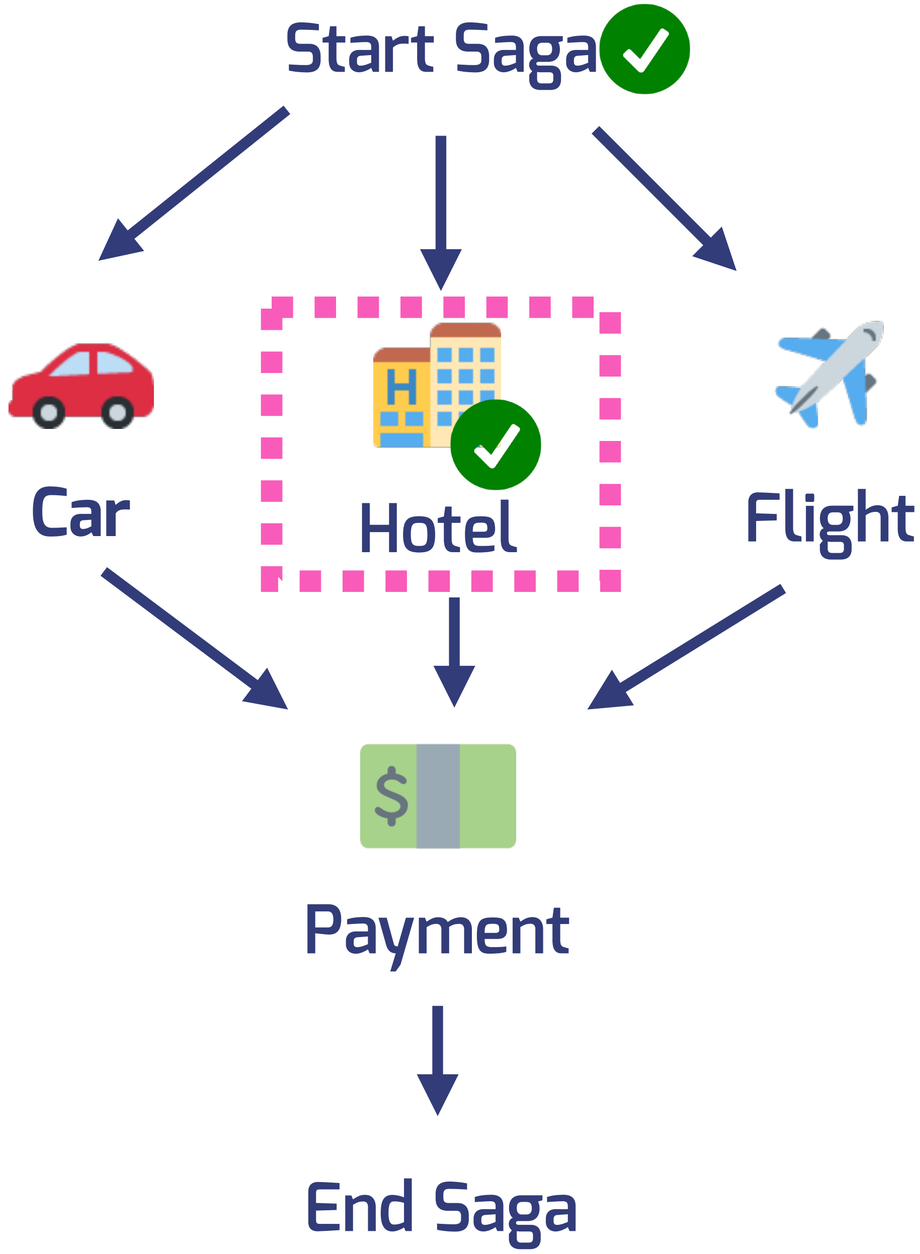

Start Hotel

End Hotel


```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```


Done





Saga Log

Start Saga

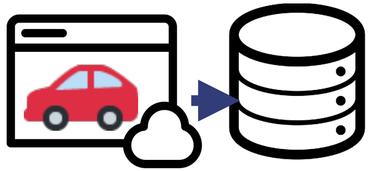

```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Q=="
}
```


Start Hotel

End Hotel


```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```


Start Car



End Saga

Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Kg=="
}
```


Start Hotel

End Hotel

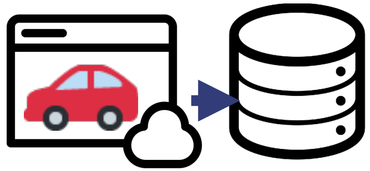

```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```


Start Car

Done

Book Car Request


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20"
}
```

Start Saga

Car

Hotel

Flight

Payment

End Saga

Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Kg=="
}
```


Start Hotel

End Hotel

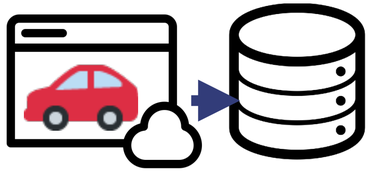

```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```

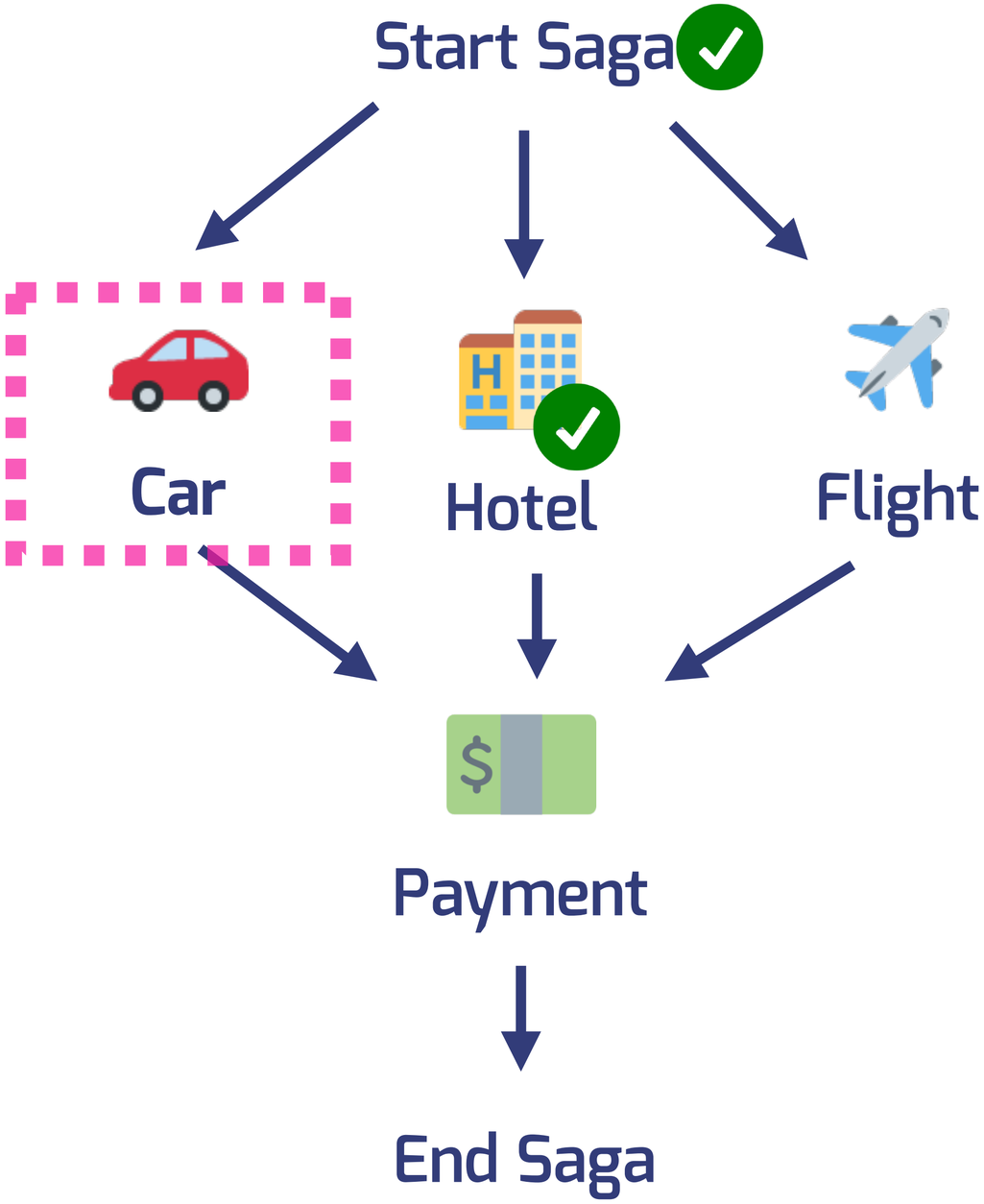

Start Car

End Car

Book Car Response


```
{
  "Success": "true",
  "Confirmation Number": "ABC456"
}
```



Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6KQ=="
}
```


Start Hotel

End Hotel

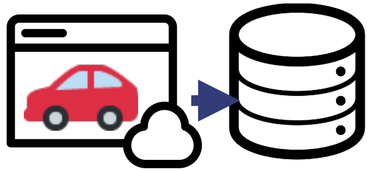

```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```

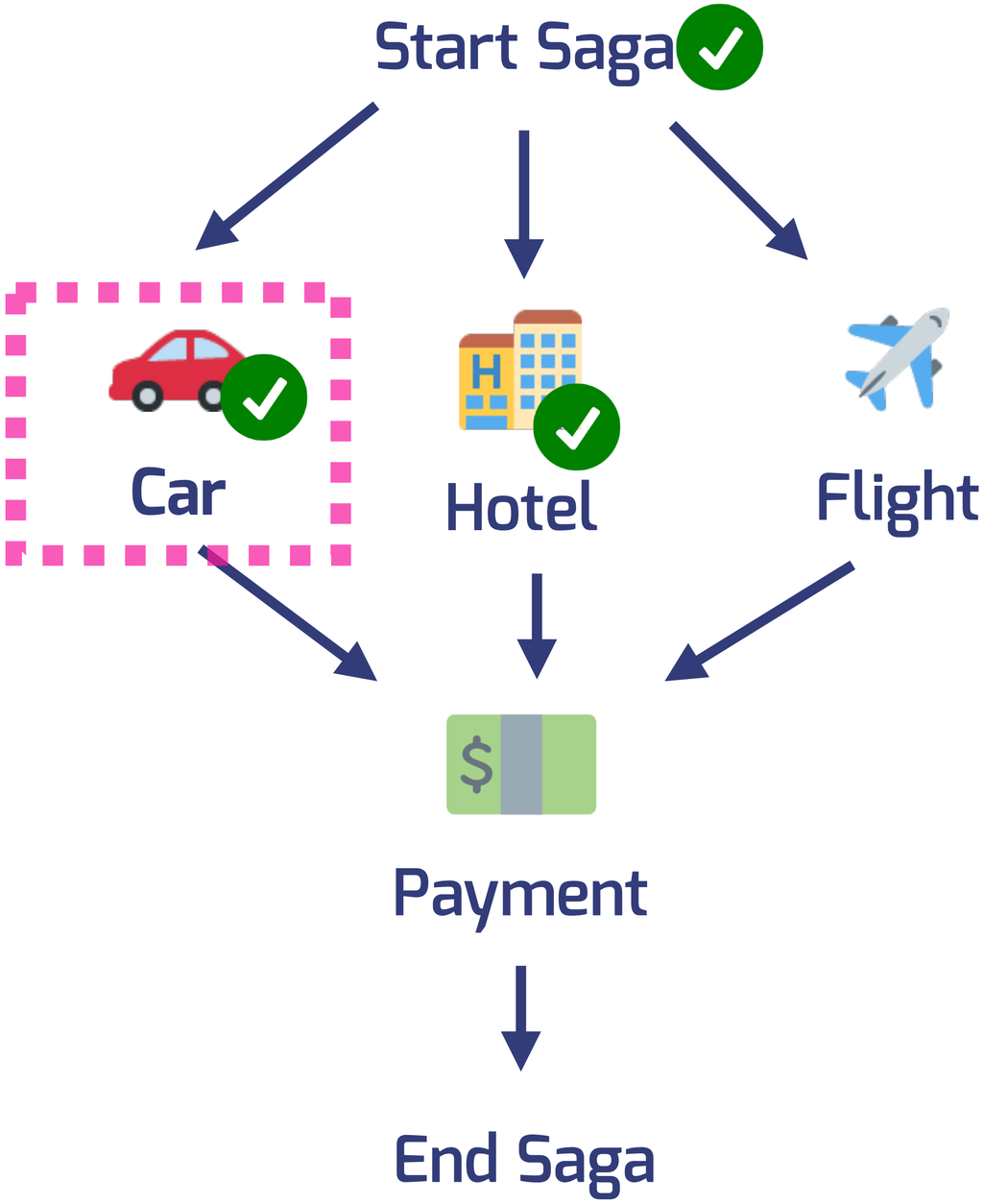

Start Car

End Car


```
{
  "Success": "true",
  "Confirmation Number": "ABC456"
}
```


Done





Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Kg=="
}
```


Start Hotel

End Hotel

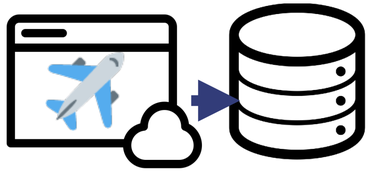

```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```

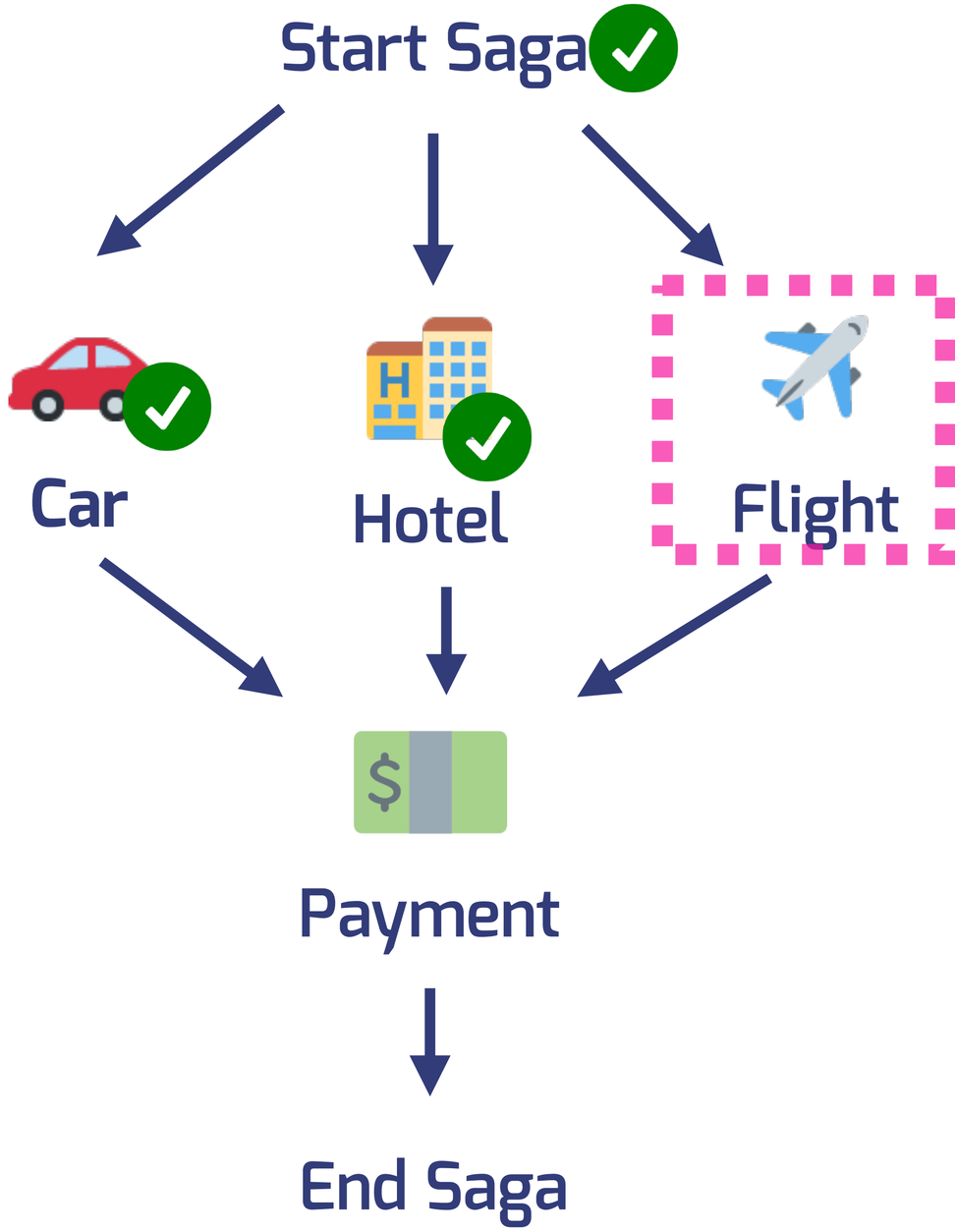

Start Car

End Car


```
{
  "Success": "true",
  "Confirmation Number": "ABC456"
}
```


Start Flight





Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Q=="
}
```


Start Hotel

End Hotel


```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```


Start Car

End Car

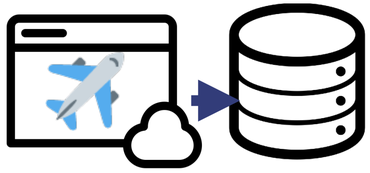

```
{
  "Success": "true",
  "Confirmation Number": "ABC456"
}
```

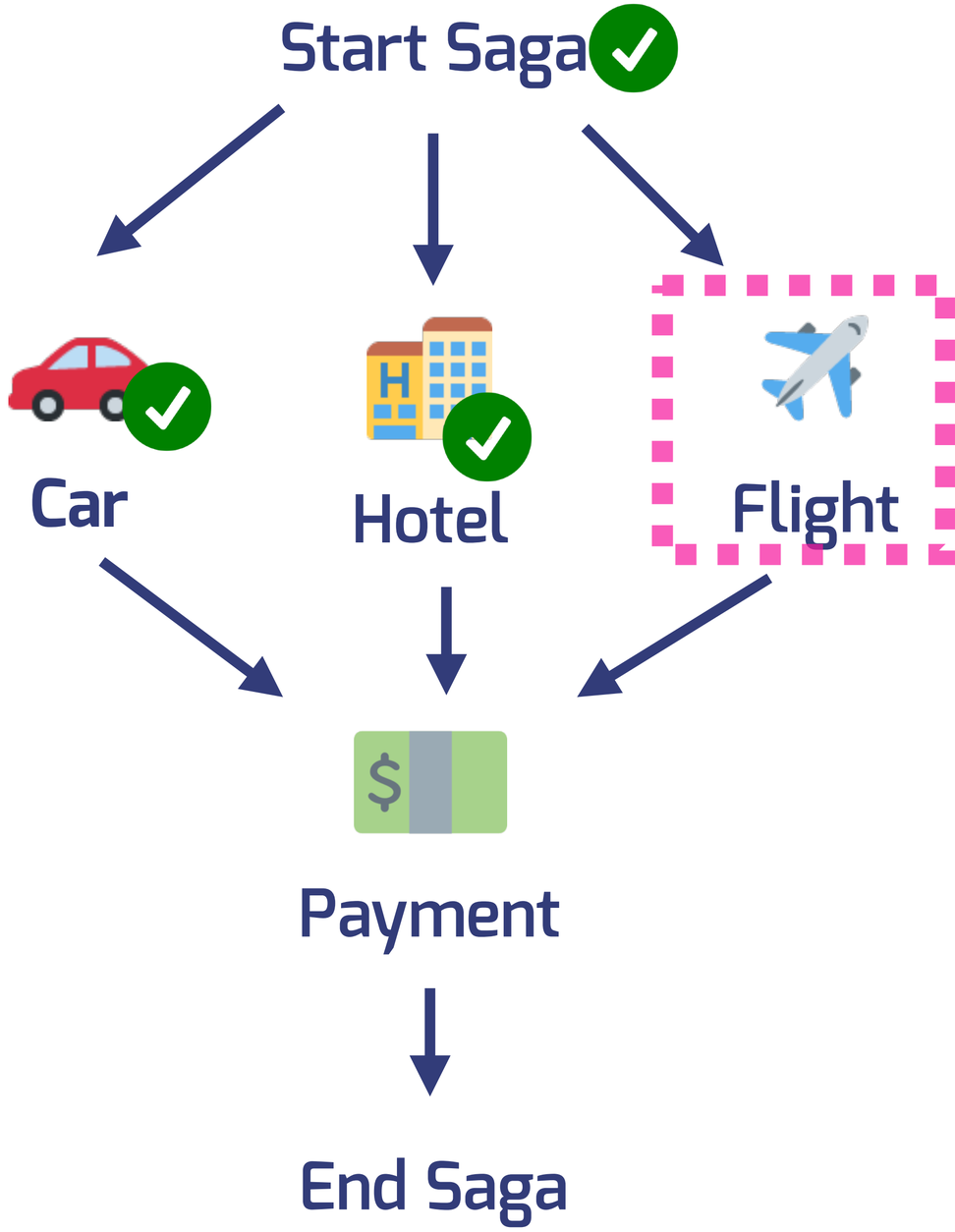

Start Flight

Done

Book Flight Request


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20"
}
```



Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Kg=="
}
```


Start Hotel

End Hotel


```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```


Start Car

End Car


```
{
  "Success": "true",
  "Confirmation Number": "ABC456"
}
```

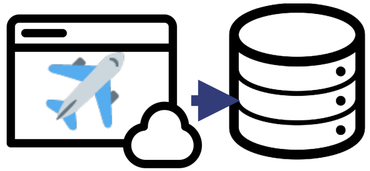

Start Flight

End Flight

SEC

Book Flight Response


```
{
  "Success": "true",
  "Confirmation Number": "789QPZ"
}
```

Start Saga

Car

Hotel

Flight

Payment

End Saga

Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Q=="
}
```


Start Hotel

End Hotel


```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```


Start Car

End Car

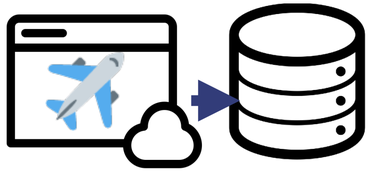

```
{
  "Success": "true",
  "Confirmation Number": "ABC456"
}
```

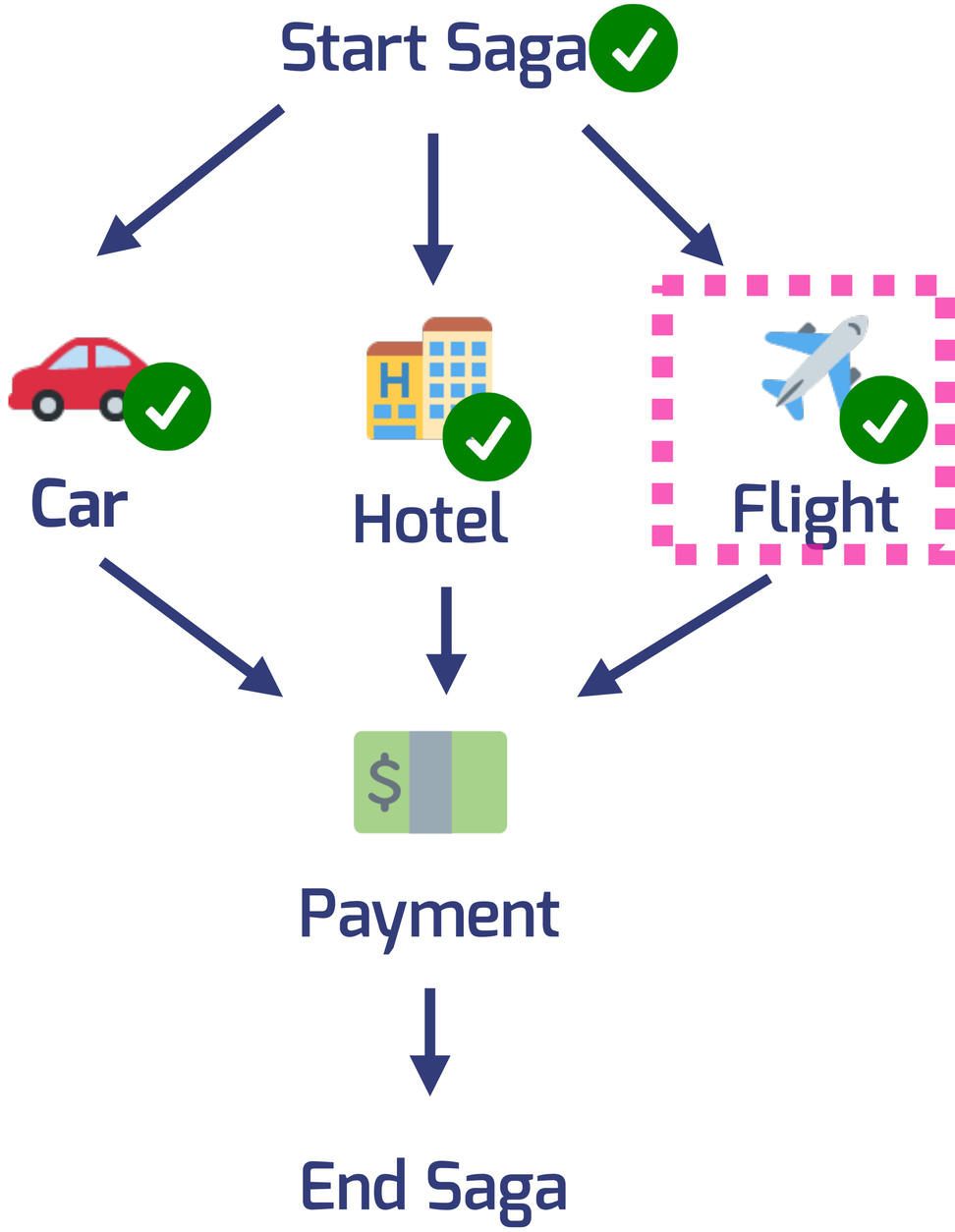

Start Flight

End Flight


```
{
  "Success": "true",
  "Confirmation Number": "789QPZ"
}
```


Done





Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Kg=="
}
```


Start Hotel

End Hotel


```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```


Start Car

End Car

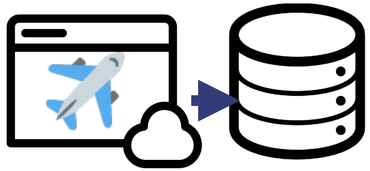

```
{
  "Success": "true",
  "Confirmation Number": "ABC456"
}
```

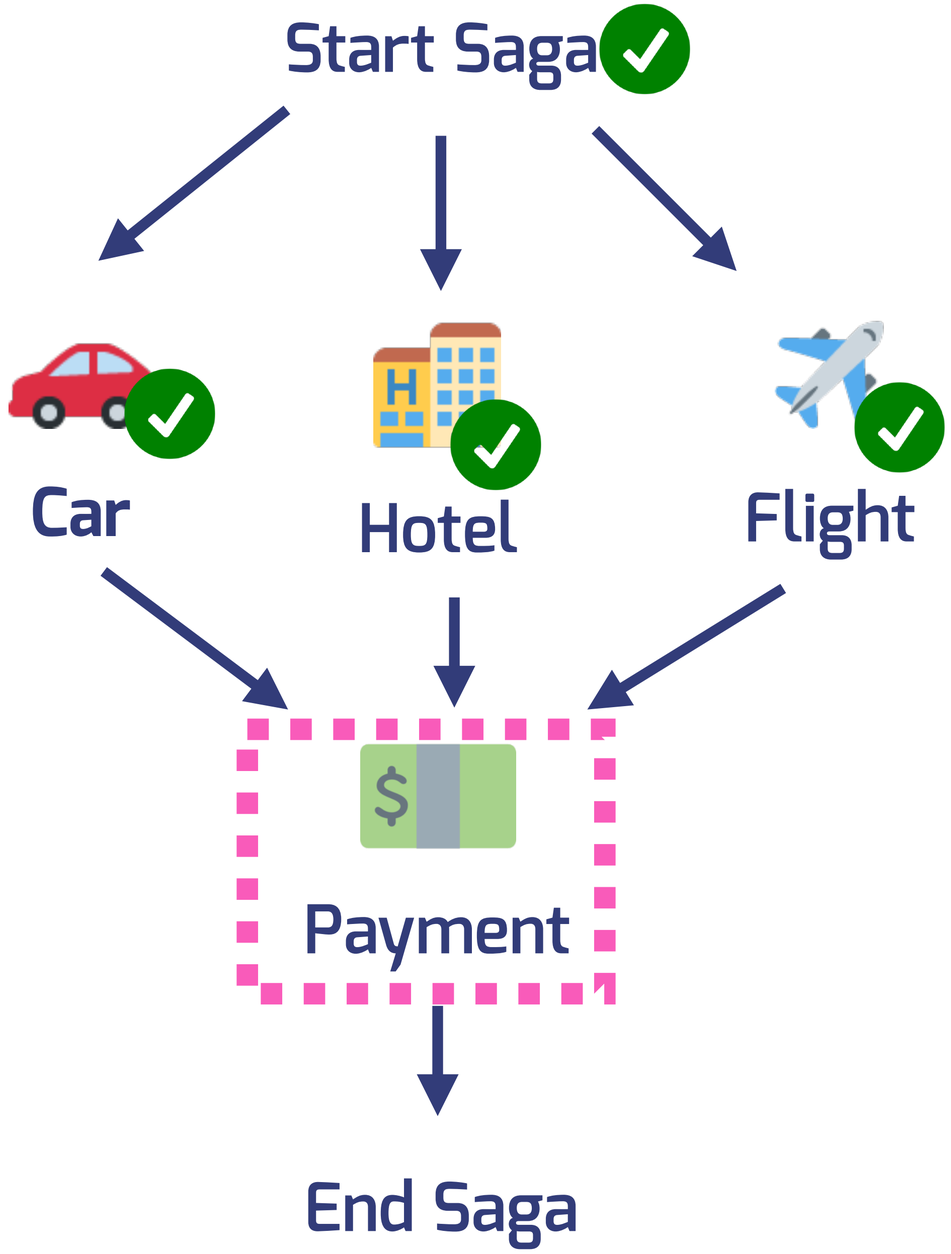

Start Flight

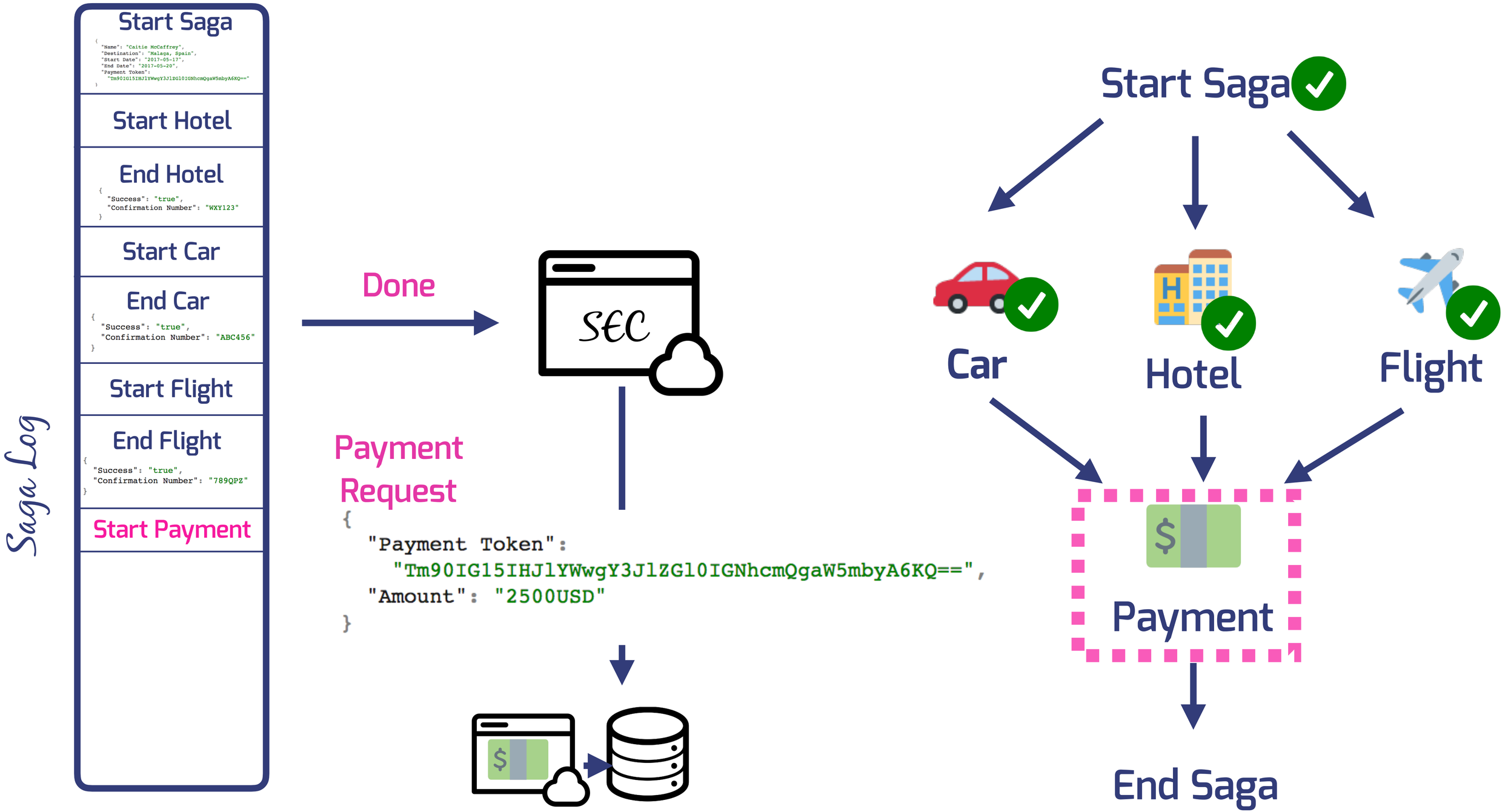
End Flight

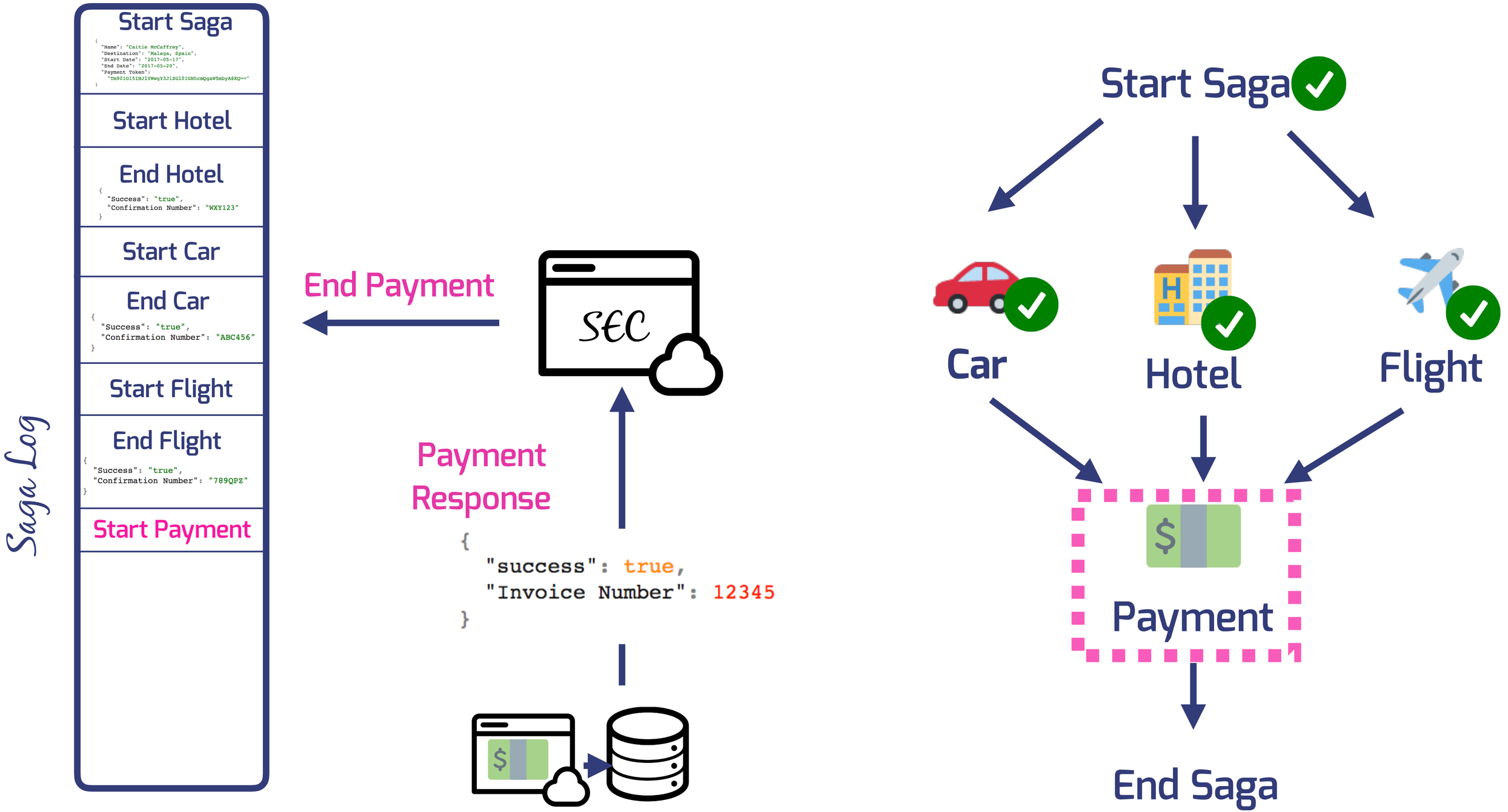

```
{
  "Success": "true",
  "Confirmation Number": "789QPZ"
}
```


Start Payment






Saga Log
Start Saga
{
"Name": "Caitie McCaffrey",
"Destination": "Malaga, Spain",
"Start Date": "2017-05-17",
"End Date": "2017-05-20",
"Payment Token":
"Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6KQ=="
}
Start Hotel
End Hotel
{
"Success": "true",
"Confirmation Number": "WXY123"
}
Start Car
End Car
{
"Success": "true",
"Confirmation Number": "ABC456"
}
Start Flight
End Flight
{
"Success": "true",
"Confirmation Number": "789QPZ"
}
Start Payment
Done
SEC
Payment Request
{
"Payment Token":
"Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6KQ==",
"Amount": "2500USD"
}
Start Saga
Car
Hotel
Flight
Payment
End Saga


Saga Log
Start Saga
{
"Name": "Caitie McCaffrey",
"Destination": "Malaga, Spain",
"Start Date": "2017-05-17",
"End Date": "2017-05-20",
"Payment Token":
"Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Q=="
}
Start Hotel
End Hotel
{
"Success": "true",
"Confirmation Number": "WXY123"
}
Start Car
End Car
{
"Success": "true",
"Confirmation Number": "ABC456"
}
Start Flight
End Flight
{
"Success": "true",
"Confirmation Number": "789QPZ"
}
Start Payment
End Payment
SEC
Payment
Response
{
"success": true,
"Invoice Number": 12345
}
Start Saga
Car
Hotel
Flight
Payment
End Saga

Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Kg=="
}
```


Start Hotel

End Hotel


```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```


Start Car

End Car


```
{
  "Success": "true",
  "Confirmation Number": "ABC456"
}
```


Start Flight

End Flight

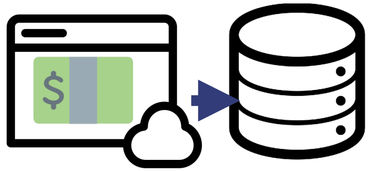

```
{
  "Success": "true",
  "Confirmation Number": "789QPZ"
}
```

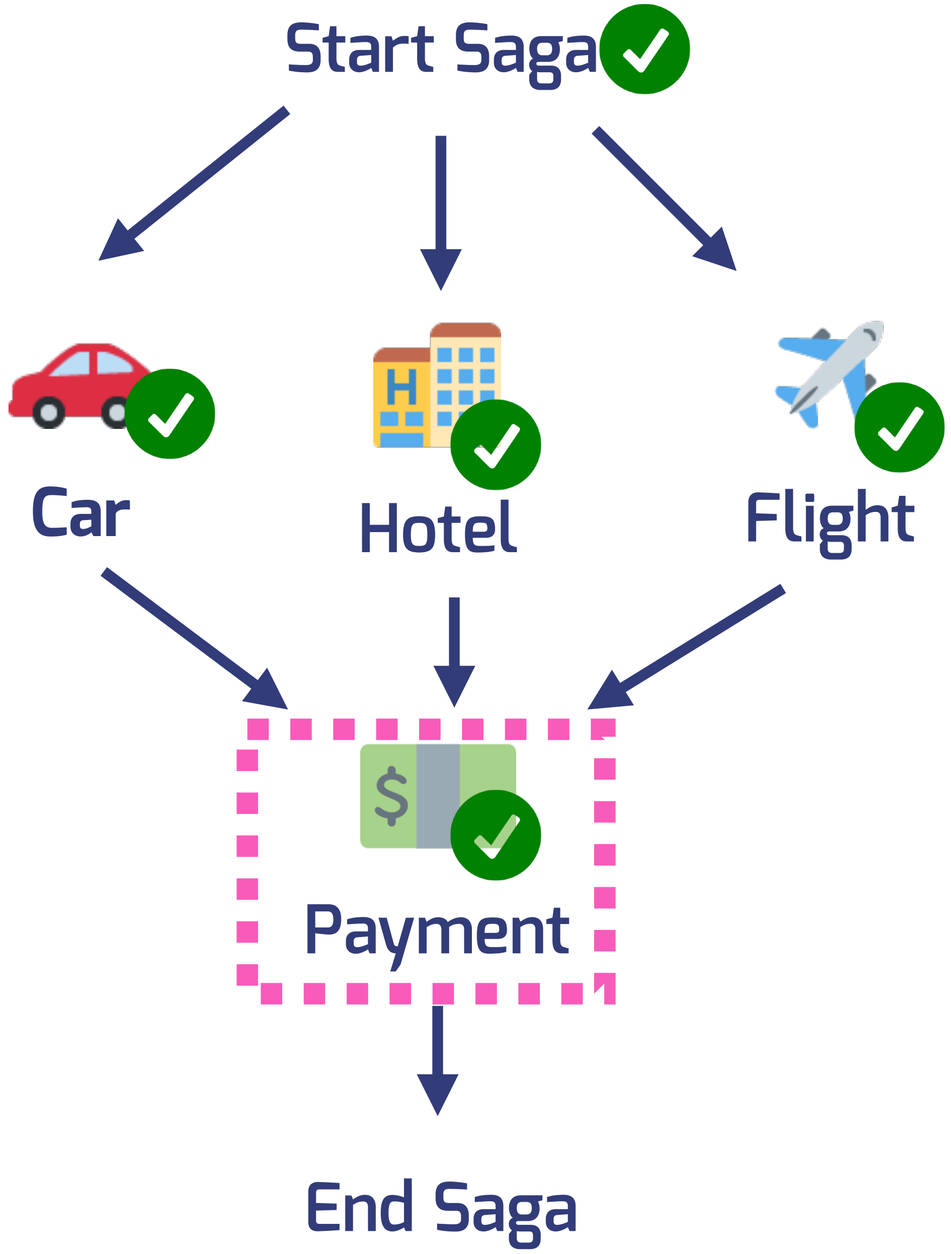

Start Payment

End Payment


```
{
  "success": true,
  "Invoice Number": 12345
}
```


Done





Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6KQ=="
}
```


Start Hotel

End Hotel


```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```


Start Car

End Car


```
{
  "Success": "true",
  "Confirmation Number": "ABC456"
}
```


Start Flight

End Flight

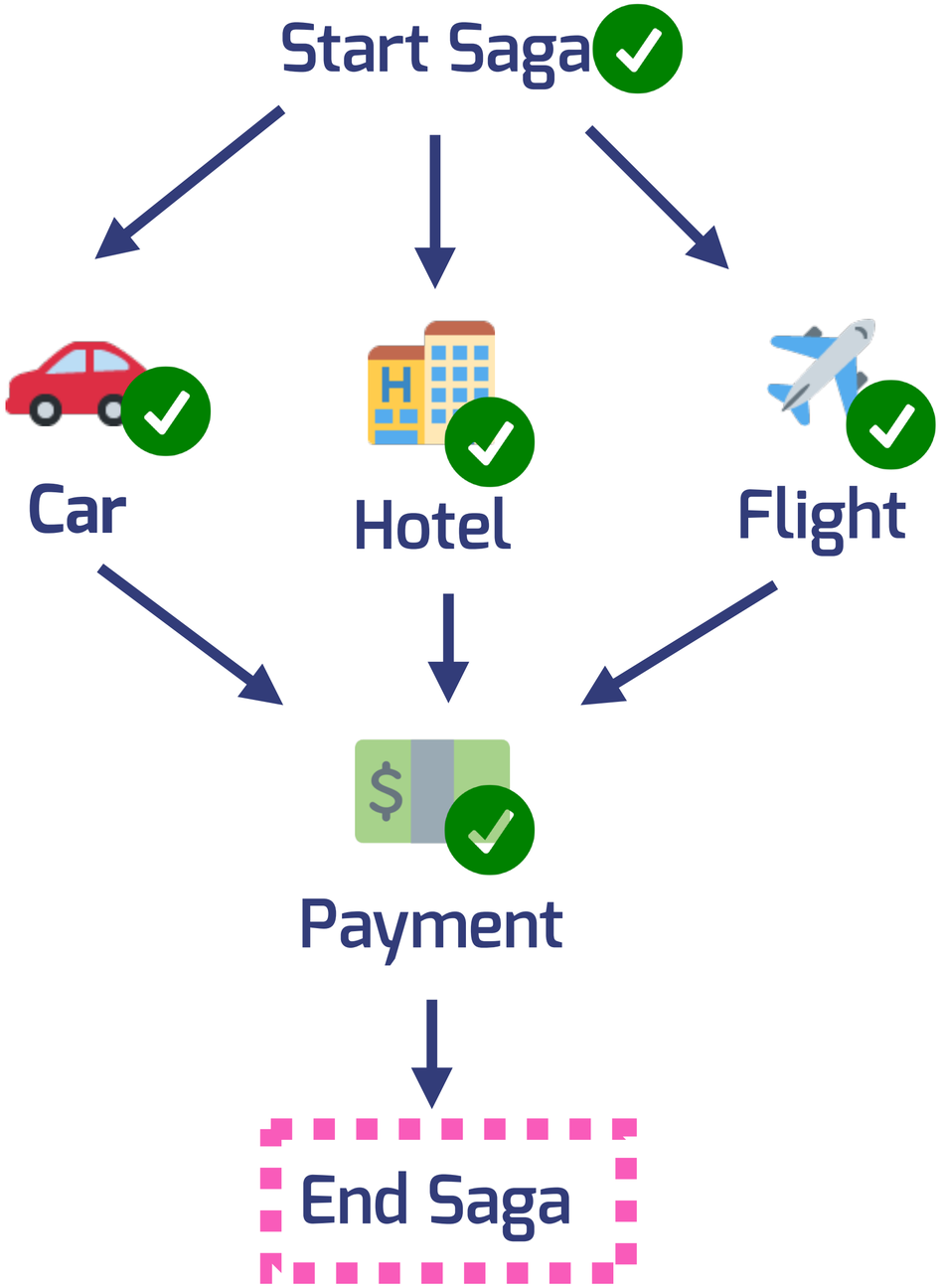

```
{
  "Success": "true",
  "Confirmation Number": "789QPZ"
}
```


Start Payment

End Payment


```
{
  "success": true,
  "Invoice Number": 12345
}
```


End Saga



Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3J1ZzlOIGNhcmQgaW5mbyA6Kg=="
}
```


Start Hotel

End Hotel


```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```


Start Car

End Car


```
{
  "Success": "true",
  "Confirmation Number": "ABC456"
}
```


Start Flight

End Flight


```
{
  "Success": "true",
  "Confirmation Number": "789QPZ"
}
```

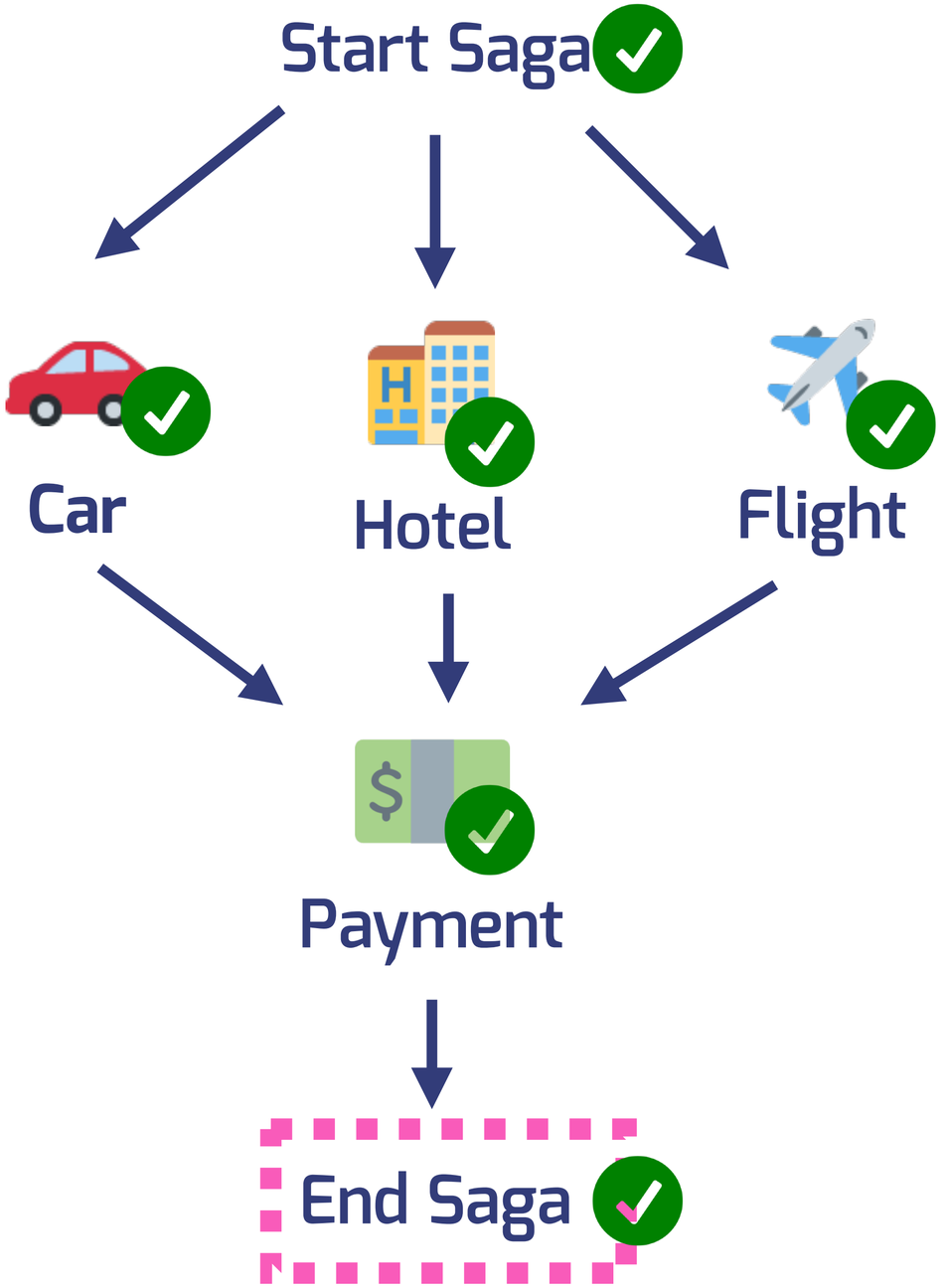

Start Payment

End Payment


```
{
  "success": true,
  "Invoice Number": 12345
}
```


End Saga

Done



Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Kg=="
}
```


Start Hotel

End Hotel


```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```


Start Car

End Car


```
{
  "Success": "true",
  "Confirmation Number": "ABC456"
}
```


Start Flight

End Flight

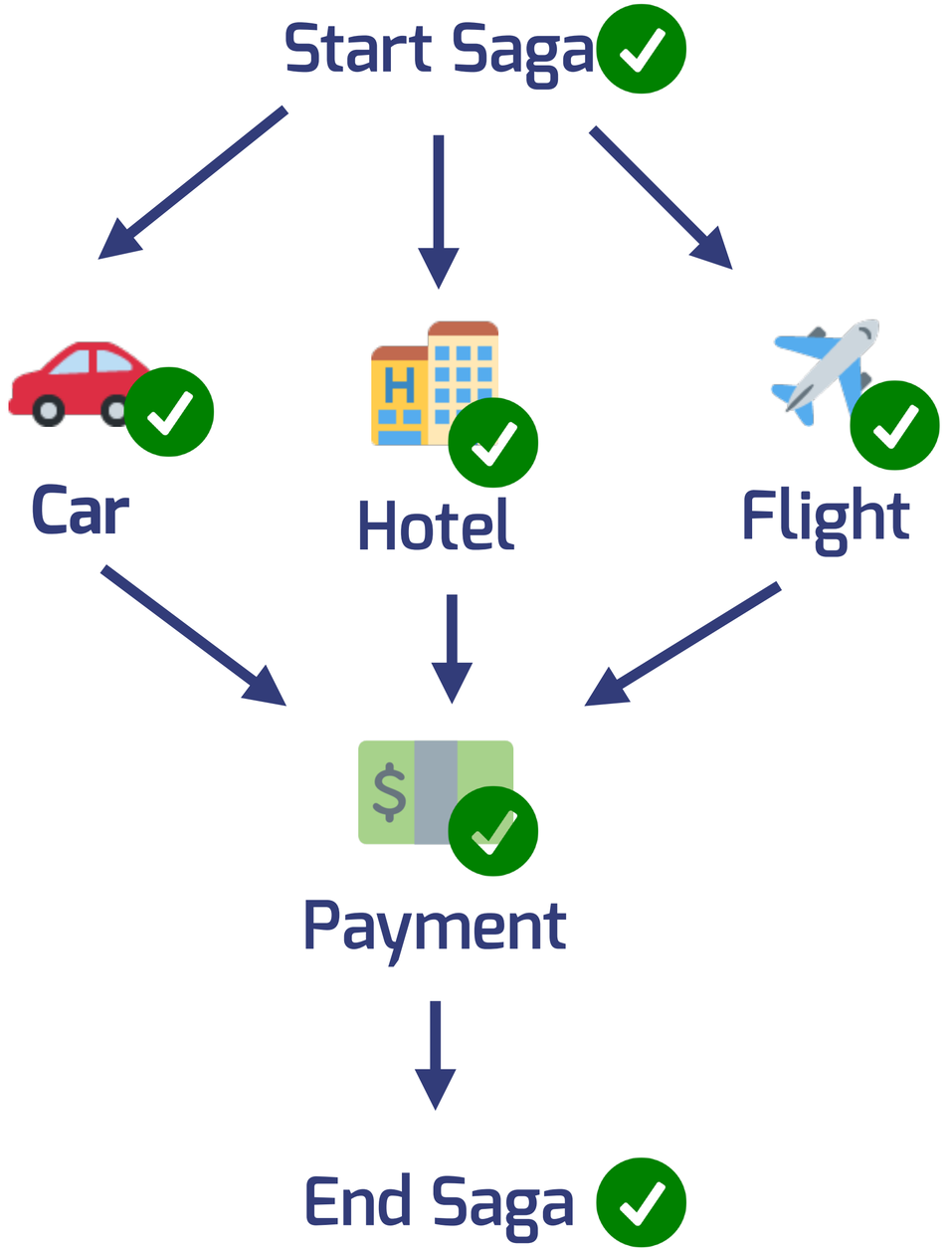

```
{
  "Success": "true",
  "Confirmation Number": "789QPZ"
}
```


Start Payment

End Payment


```
{
  "success": true,
  "Invoice Number": 12345
}
```


End Saga



Failure of a

Distributed Saga

Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Kg=="
}
```


Start Hotel

End Hotel

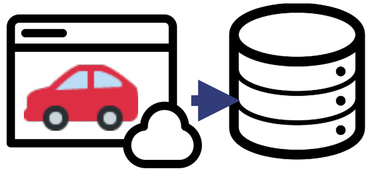

```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```

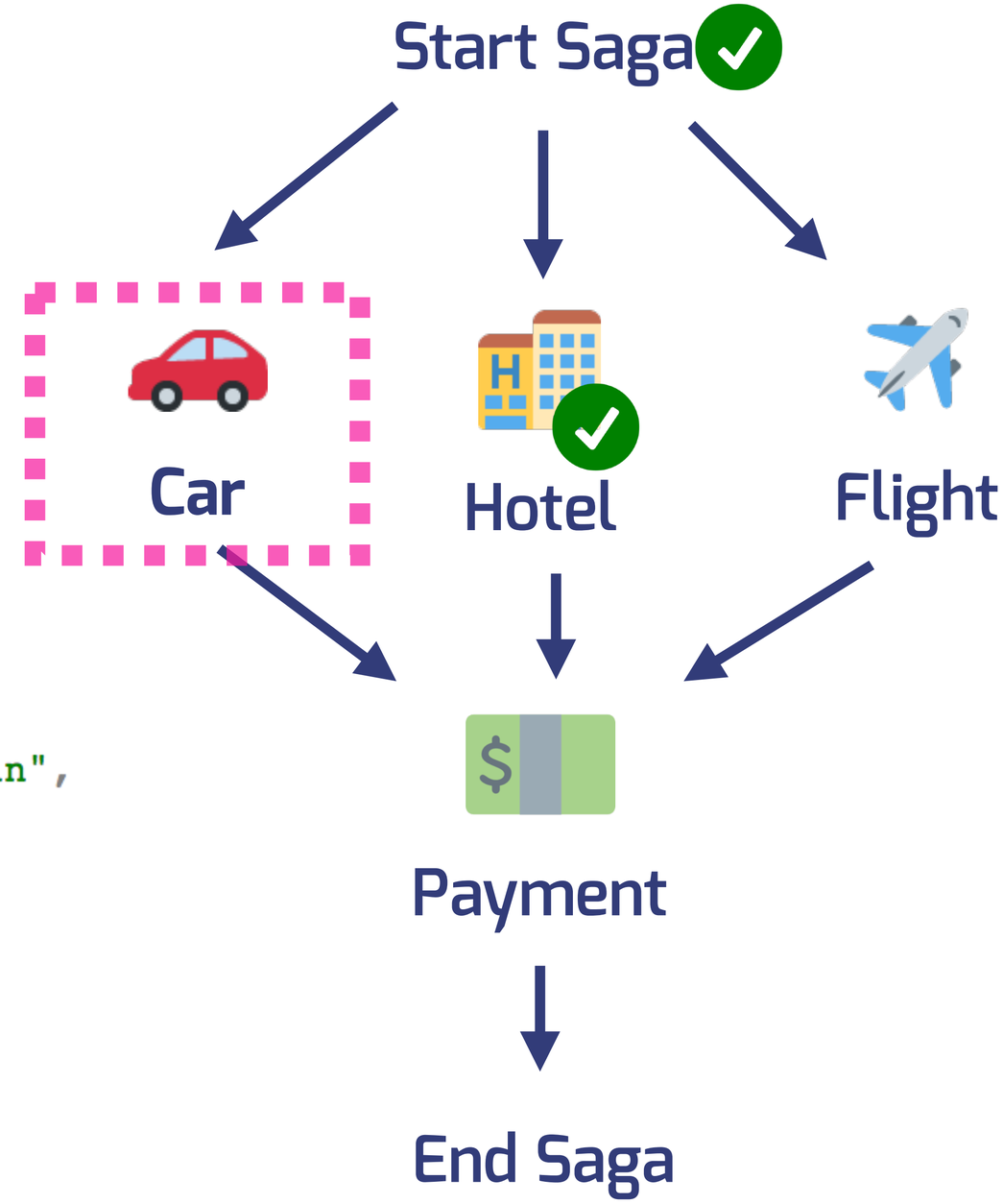

Start Flight

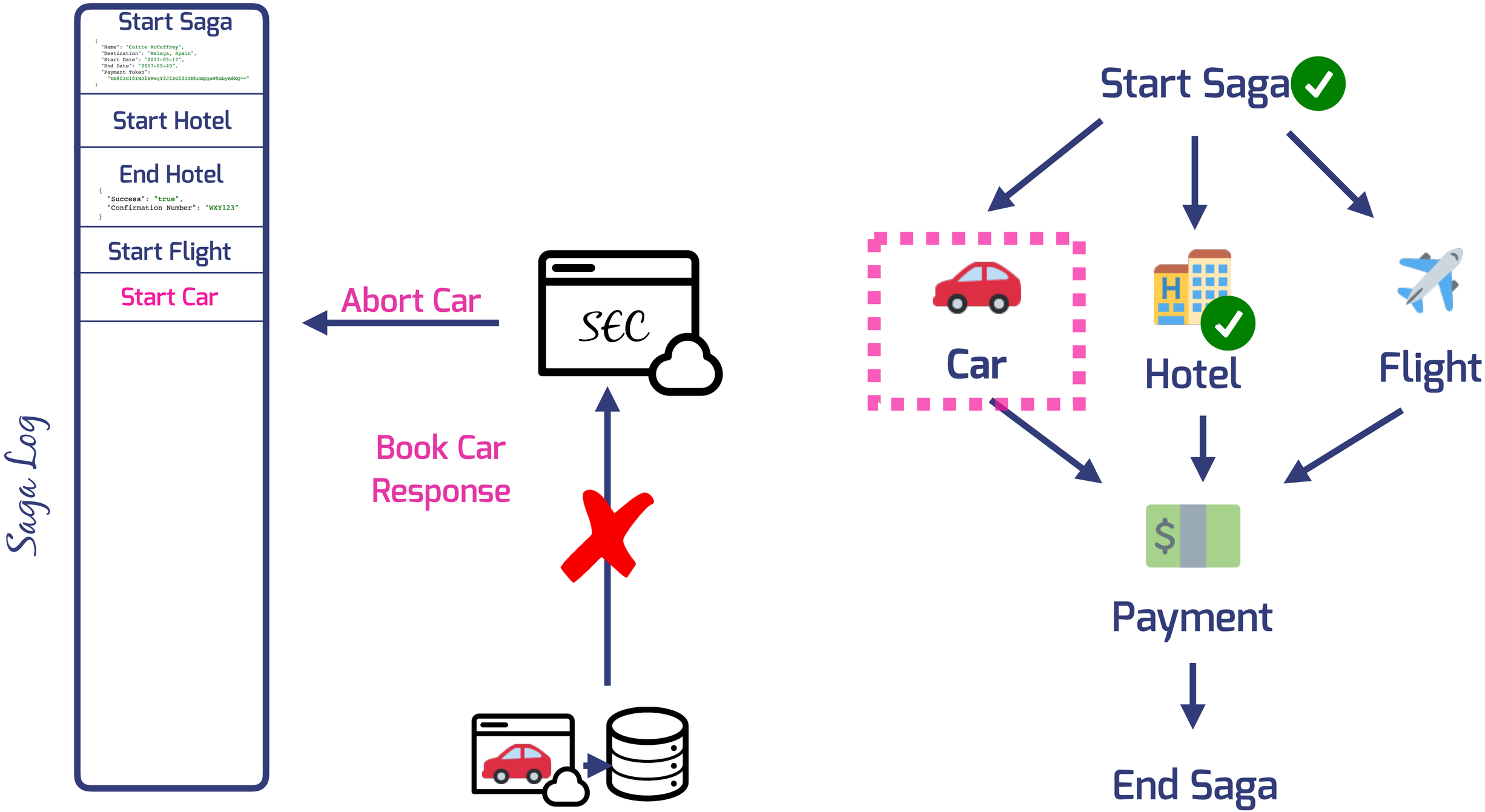
Start Car

Book Car Request


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20"
}
```




Saga Log
Start Saga
{
"Name": "Caitie McCaffrey",
"Destination": "Malaga, Spain",
"Start Date": "2017-05-17",
"End Date": "2017-05-20",
"Payment Token":
"Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6KQ=="
}
Start Hotel
End Hotel
{
"Success": "true",
"Confirmation Number": "WXY123"
}
Start Flight
Start Car
Abort Car
SEC
Book Car
Response
Start Saga
Car
Hotel
Flight
Payment
End Saga

Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6KQ=="
}
```


Start Hotel

End Hotel

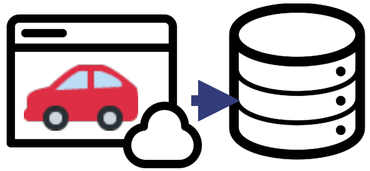

```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```

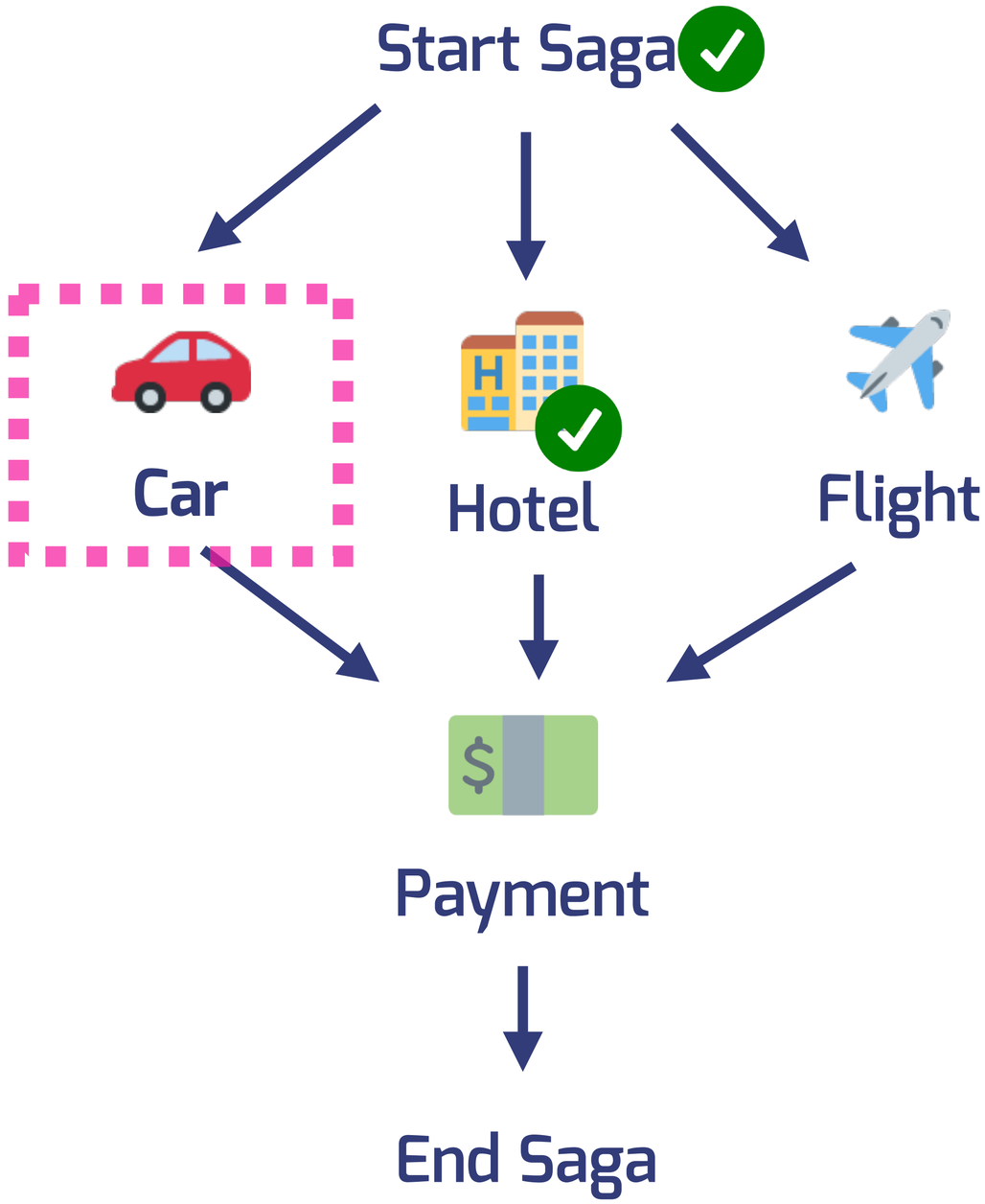

Start Flight

Start Car

Abort Car

Done





Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6KQ=="
}
```


Start Hotel

End Hotel


```
{
  "Success": "true",
  "Confirm
}
```


Sta

St

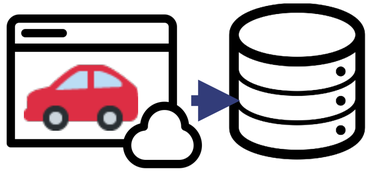
Ab

Saga Log

Rollback Recovery

Start Saga

ght



End Saga

Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6KQ=="
}
```


Start Hotel

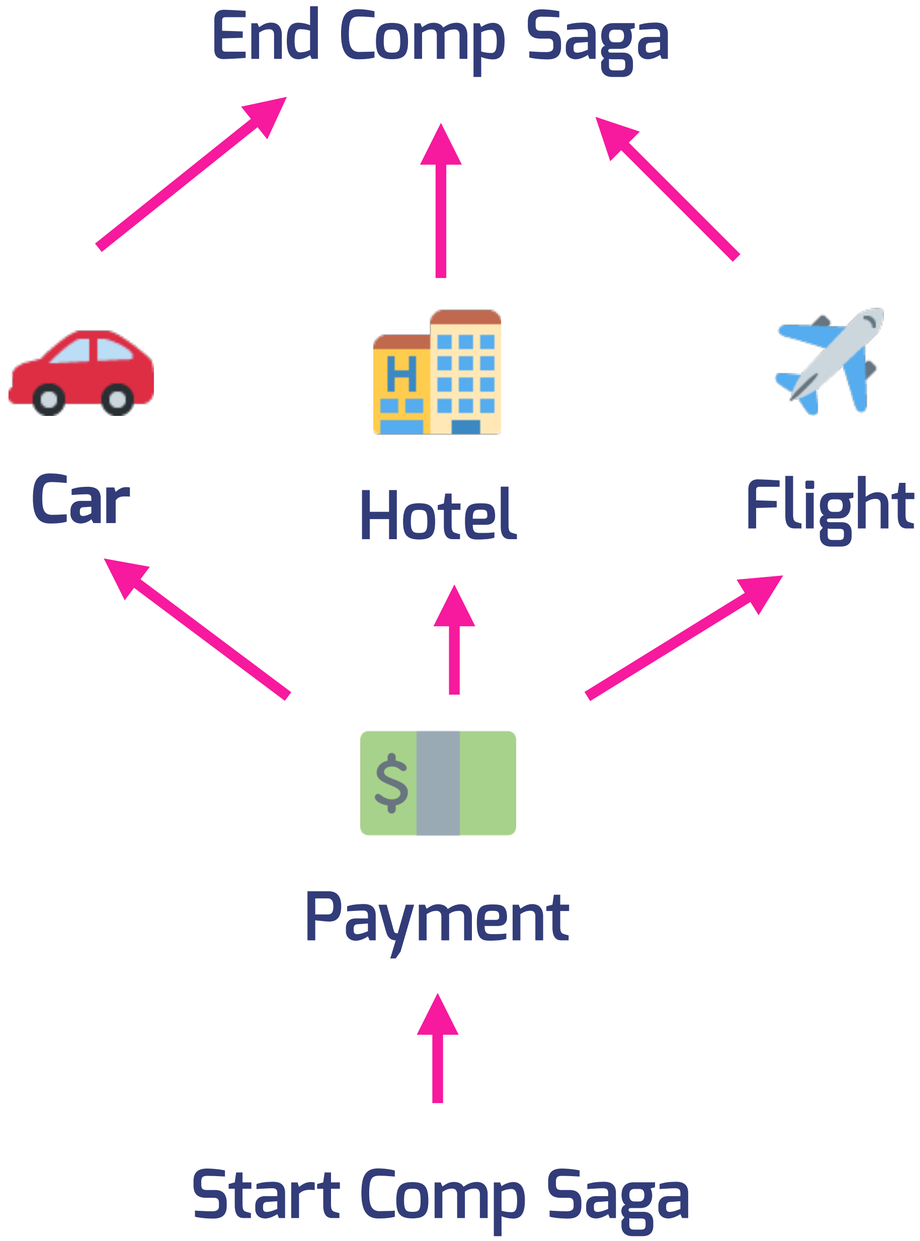
End Hotel


```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```


Start Flight

Start Car

Abort Car



Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6KQ=="
}
```


Start Hotel

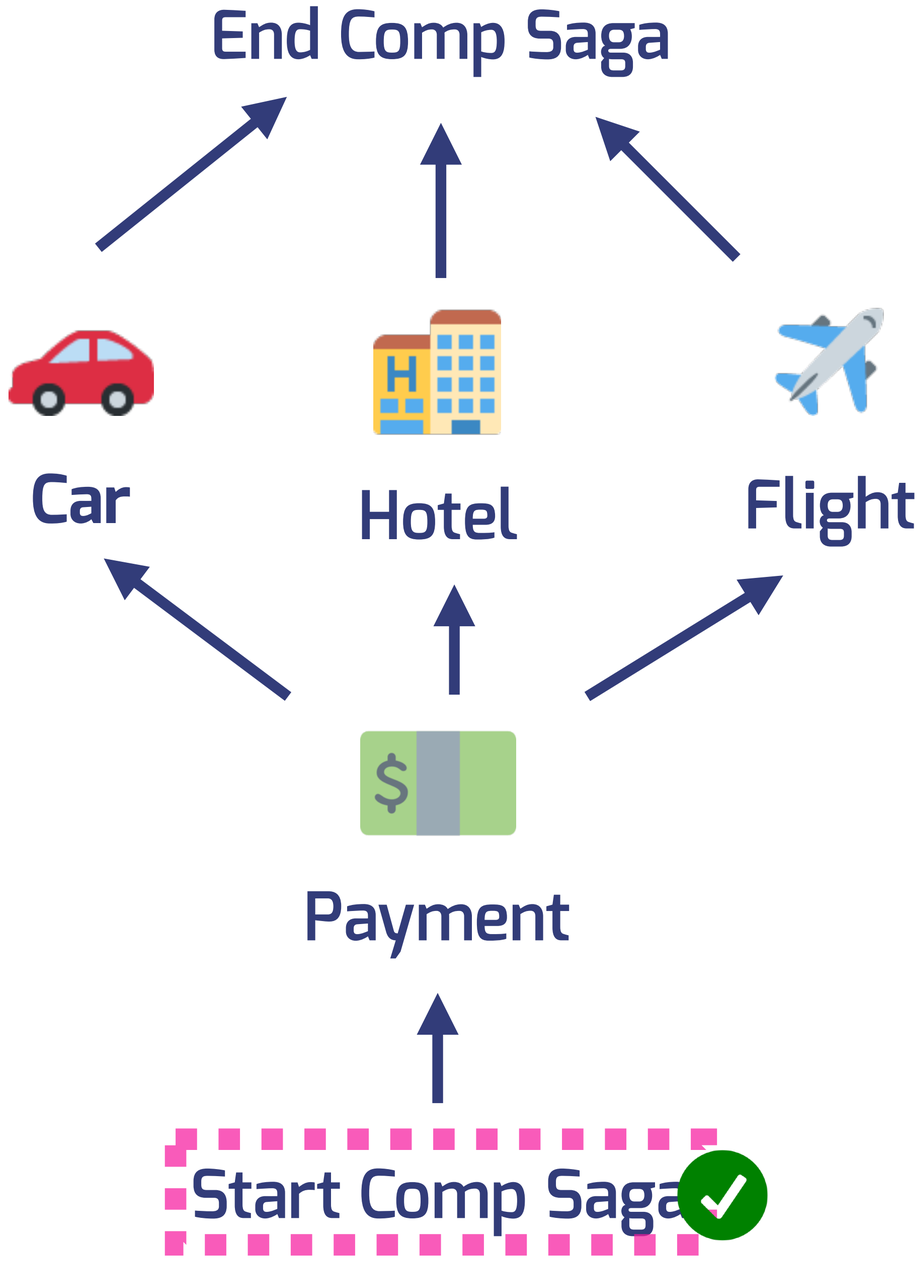
End Hotel


```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```


Start Flight

Start Car

Abort Car



Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Kg=="
}
```


Start Hotel

End Hotel


```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```


Start Flight

Start Car

Abort Car

Payment Log Entries?

End Comp Saga

Car

Hotel

Flight

Payment

Start Comp Saga

Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Kg=="
}
```


Start Hotel

End Hotel

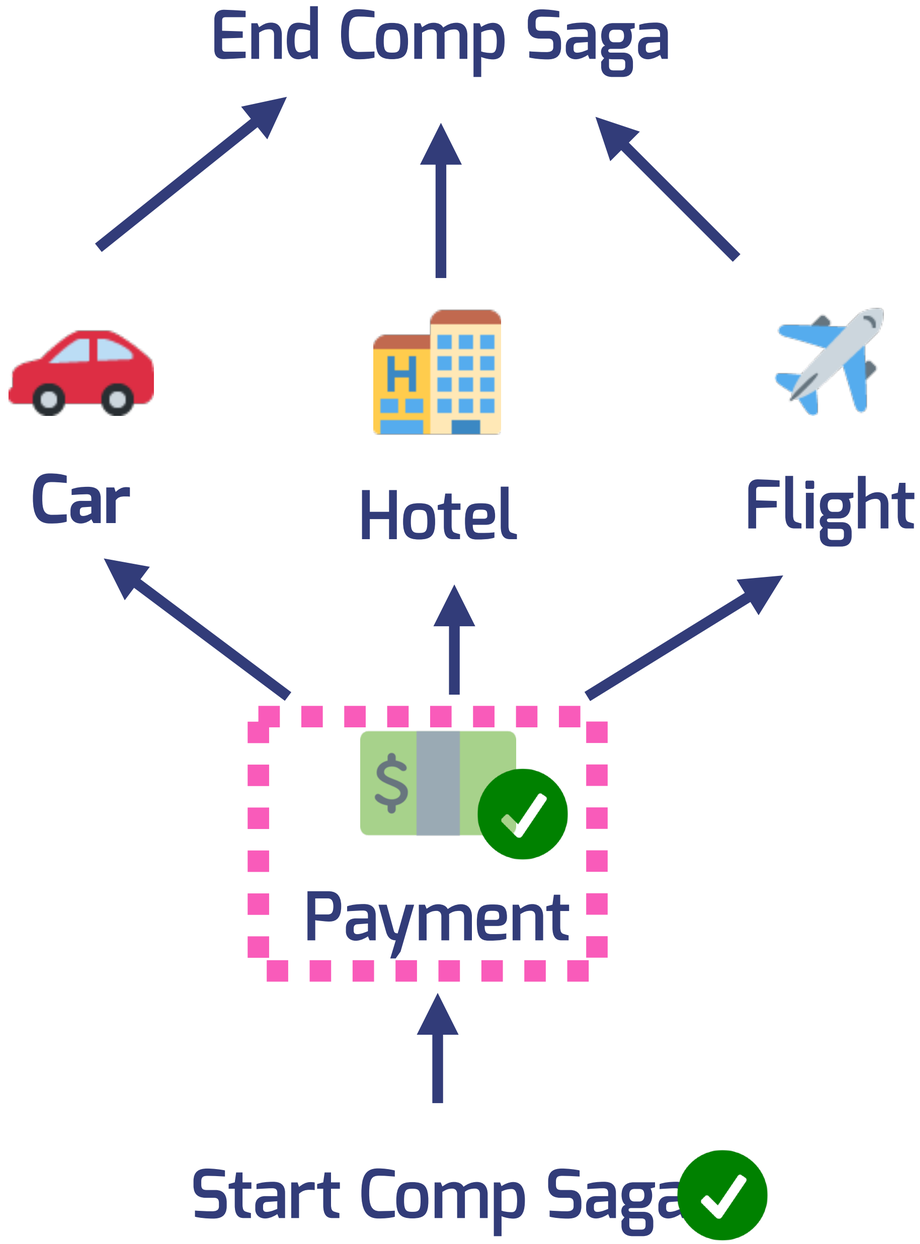

```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```


Start Flight

Start Car

Abort Car

{ }



Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Kg=="
}
```


Start Hotel

End Hotel


```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```


Start Flight

Start Car

Abort Car

Car Log Entries?

End Comp Saga

Car

Hotel

Flight

Payment

Start Comp Saga

Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Kg=="
}
```


Start Hotel

End Hotel

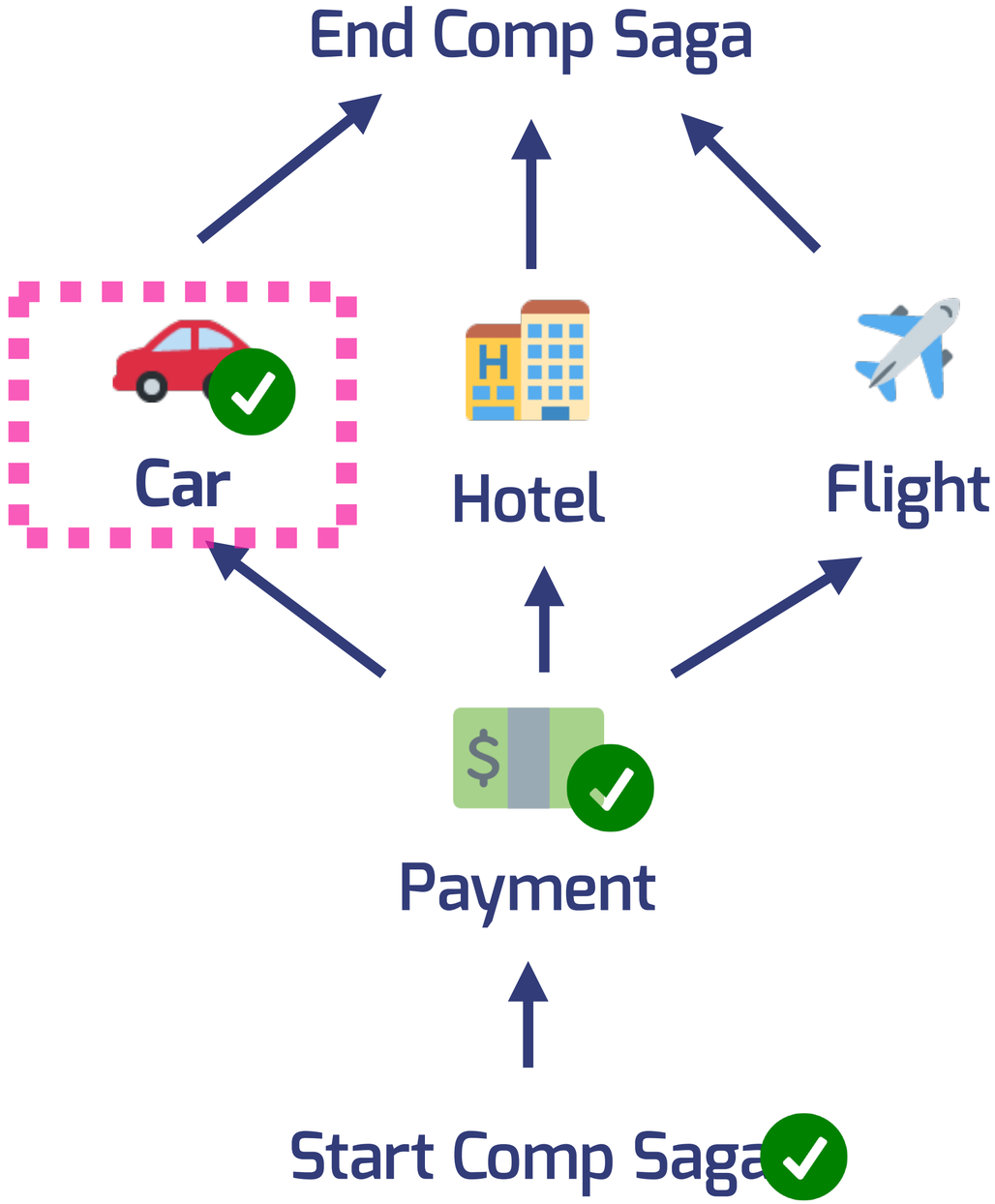

```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```


Start Flight

Start Car

Abort Car

{ Start, Abort }



Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Kg=="
}
```


Start Hotel

End Hotel

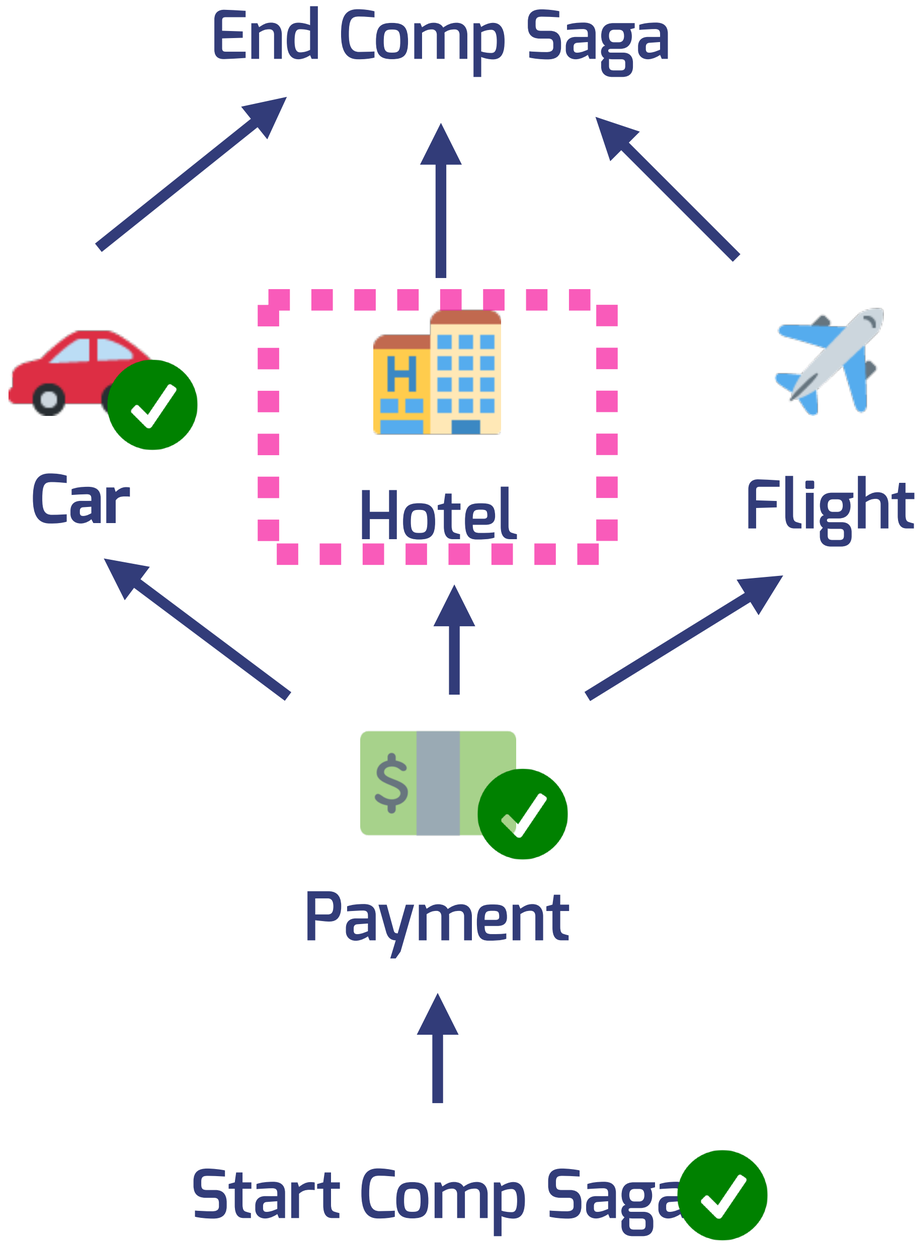

```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```


Start Flight

Start Car

Abort Car

Hotel Log Entries?



Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6KQ=="
}
```


Start Hotel

End Hotel

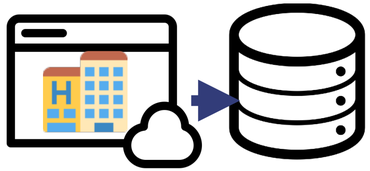

```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```

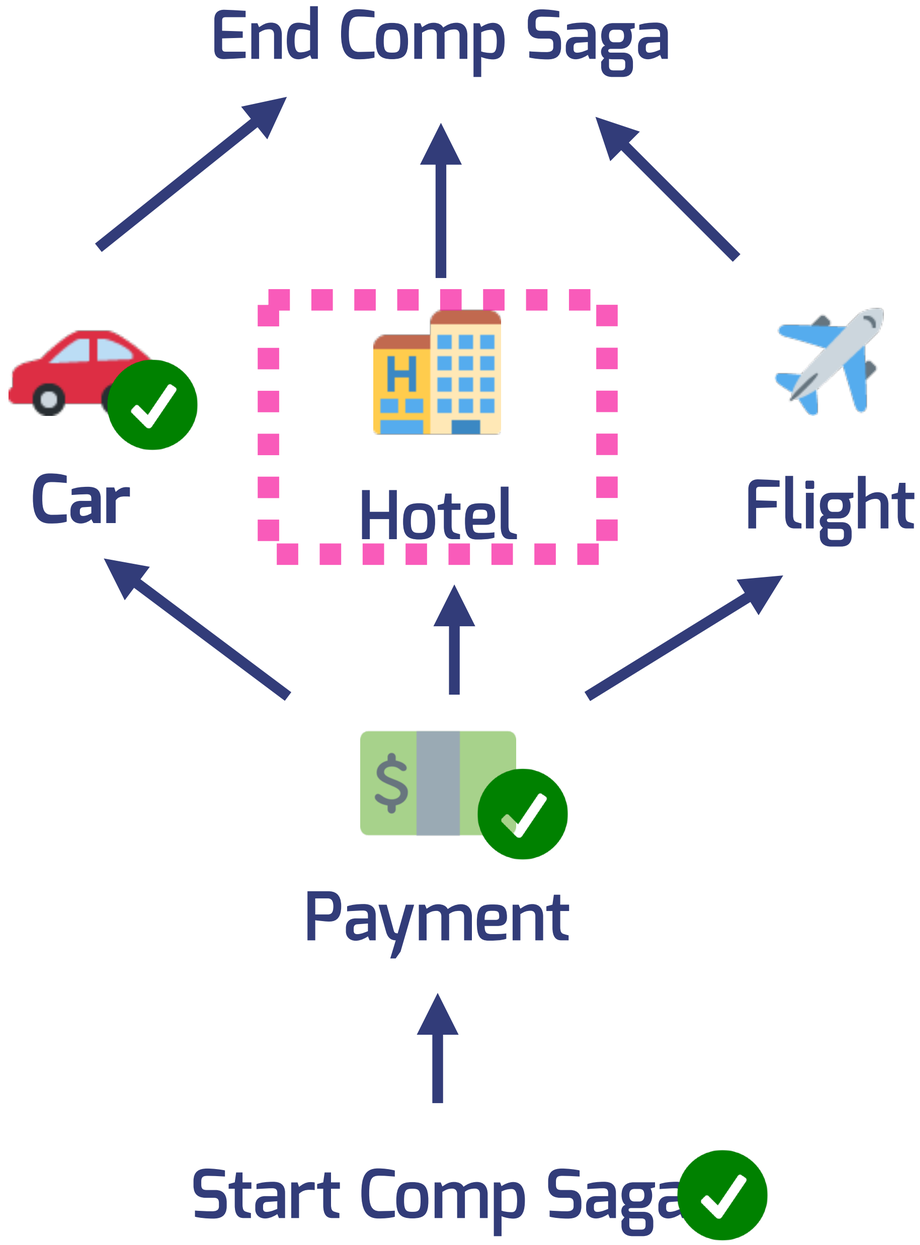

Start Flight

Start Car

Abort Car

{ Start, End }





Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Kg=="
}
```


Start Hotel

End Hotel


```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```


Start Flight

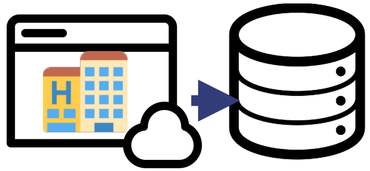
Start Car

Abort Car

{ Start, End }

Cancel Hotel Request


```
{
  "Name": "Caitie McCaffrey",
  "Confirmation Number": "WXY123"
}
```

End Comp Saga

Car

Hotel

Flight

Payment

Start Comp Saga

Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Kg=="
}
```


Start Hotel

End Hotel

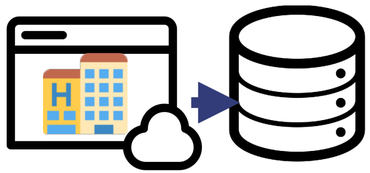

```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```

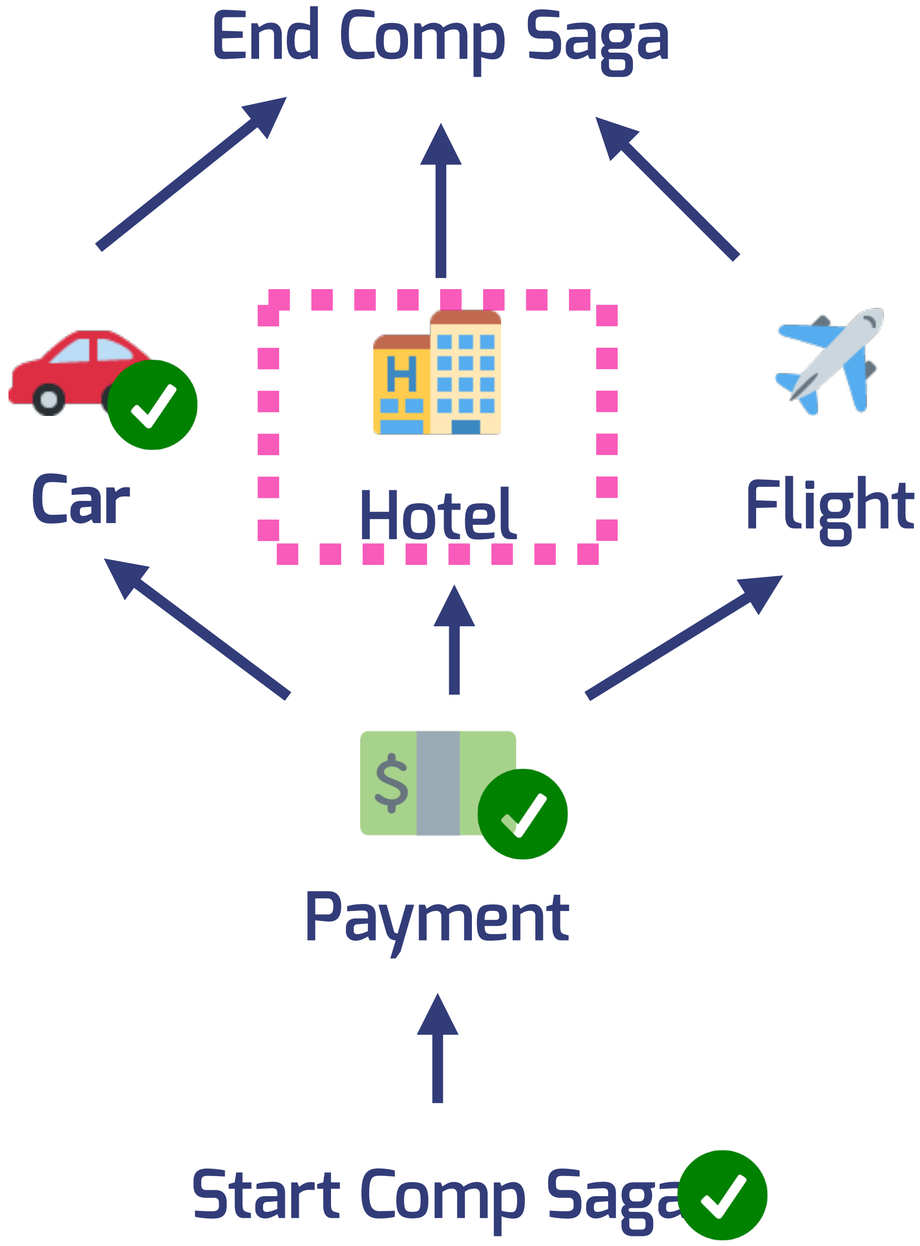

Start Flight

Start Car

Abort Car


```
{
  "success": "true",
  "Confirmation Number": "WXY123"
}
```



Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6KQ=="
}
```


Start Hotel

End Hotel


```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```

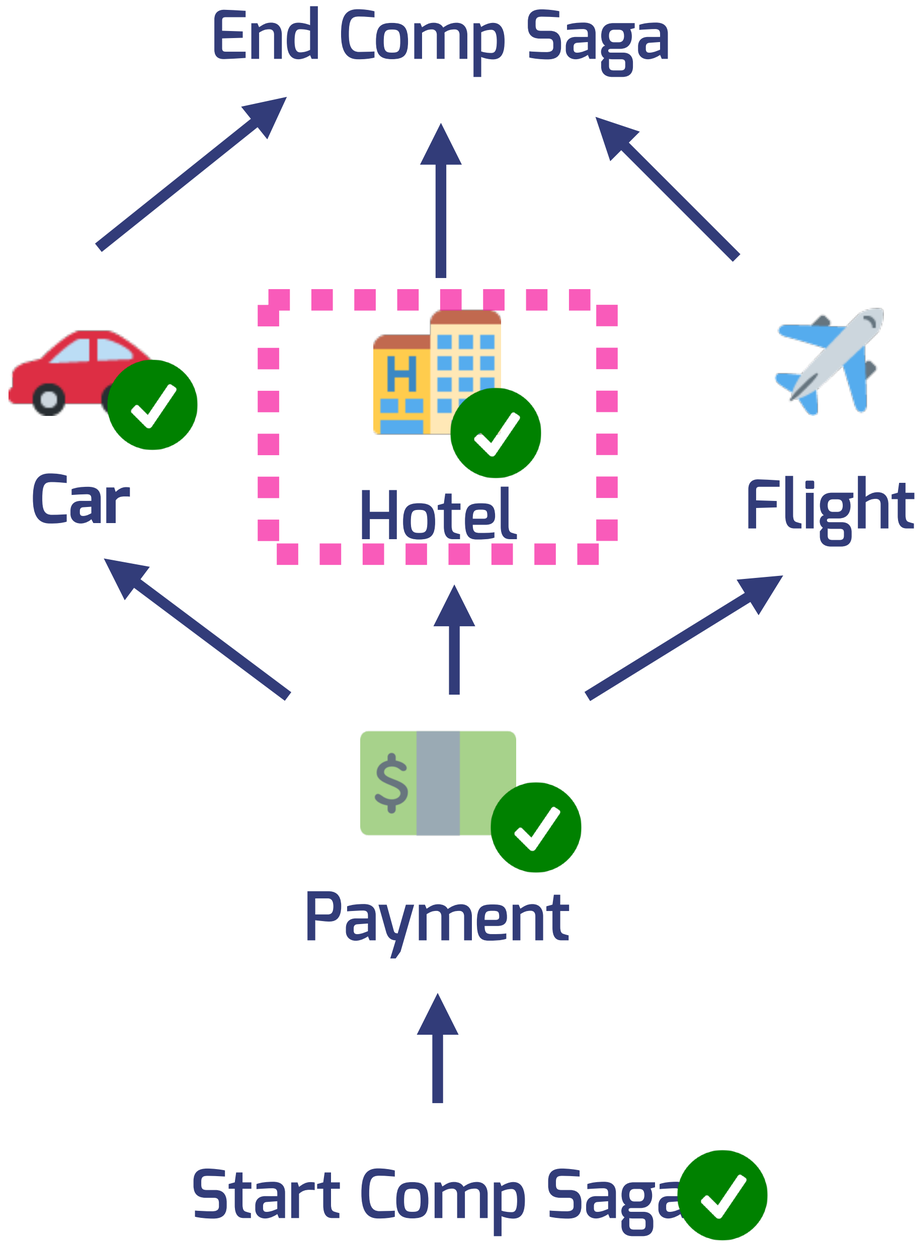

Start Flight

Start Car

Abort Car

Comp Hotel

Done



Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Kg=="
}
```


Start Hotel

End Hotel


```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```

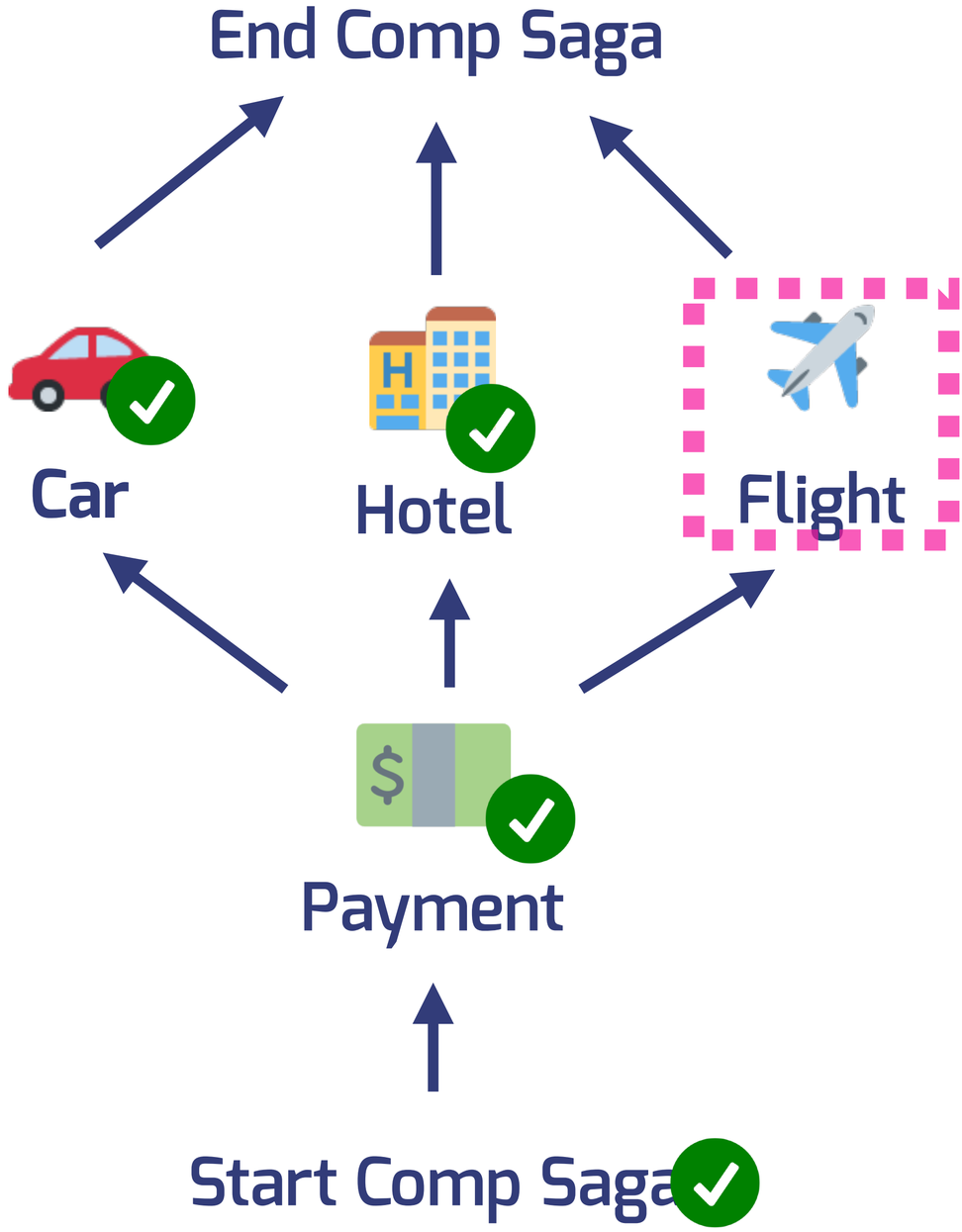

Start Flight

Start Car

Abort Car

Comp Hotel

Flight Log Entries?



Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6KQ=="
}
```


Start Hotel

End Hotel


```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```


Start Flight

Start Car

Abort Car

Comp Hotel

{ Start }

End Comp Saga

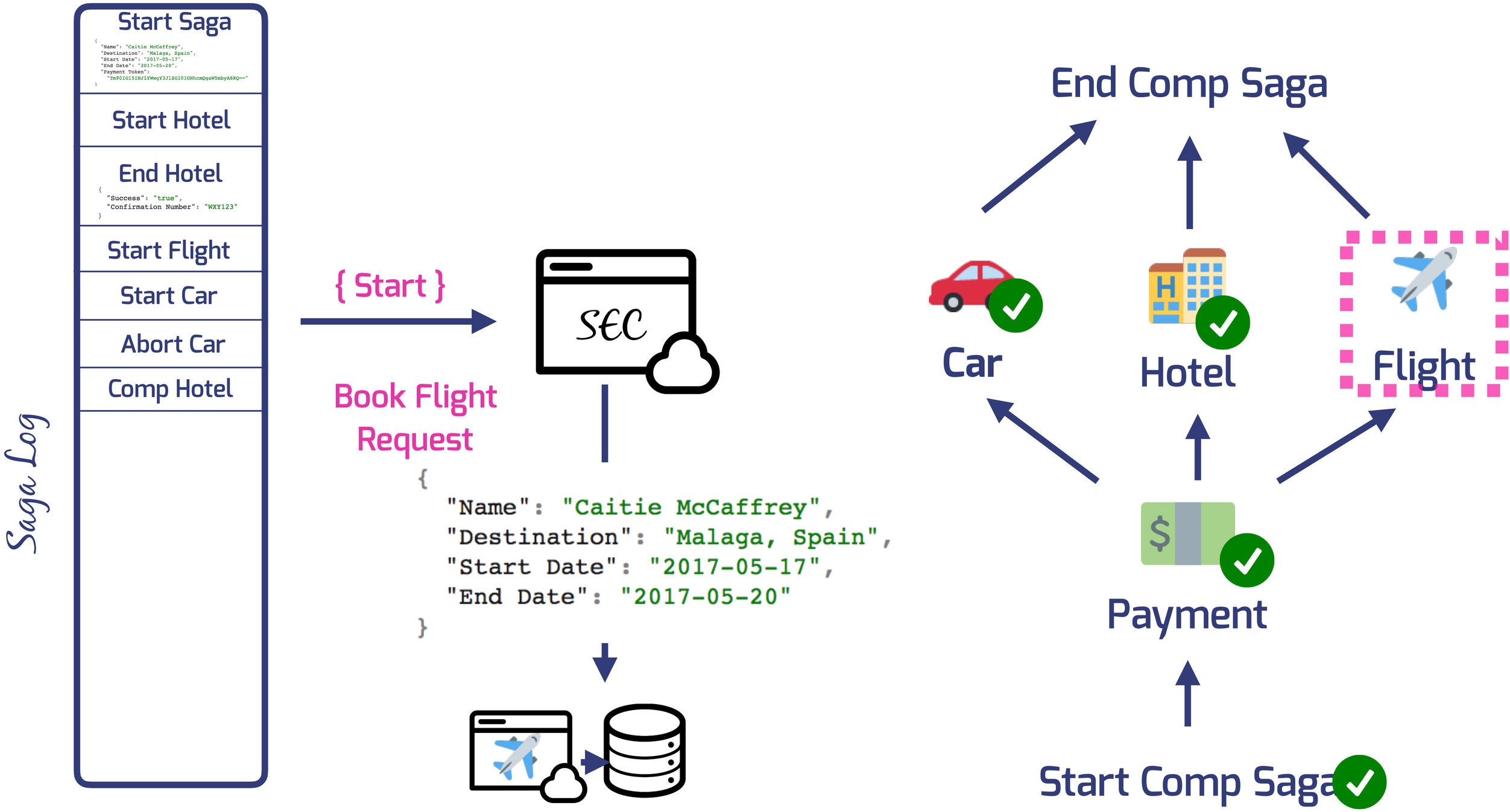
Car

Hotel

Flight

Payment

Start Comp Saga


Saga Log
Start Saga
{
"Name": "Caitie McCaffrey",
"Destination": "Malaga, Spain",
"Start Date": "2017-05-17",
"End Date": "2017-05-20",
"Payment Token":
"Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6KQ=="
}
Start Hotel
End Hotel
{
"Success": "true",
"Confirmation Number": "WXY123"
}
Start Flight
Start Car
Abort Car
Comp Hotel
{ Start }
SEC
Book Flight Request
{
"Name": "Caitie McCaffrey",
"Destination": "Malaga, Spain",
"Start Date": "2017-05-17",
"End Date": "2017-05-20"
}
End Comp Saga
Car
Hotel
Flight
Payment
Start Comp Saga

Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6Kg=="
}
```


Start Hotel

End Hotel


```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```


Start Flight

Start Car

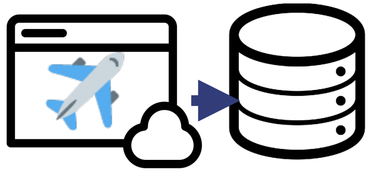
Abort Car

Comp Hotel

End Flight

Book Flight Response


```
{
  "Success": "true",
  "Confirmation Number": "789QPZ"
}
```

End Comp Saga

Car

Hotel

Flight

Payment

Start Comp Saga

Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6KQ=="
}
```


Start Hotel

End Hotel


```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```


Start Flight

Start Car

Abort Car

Comp Hotel

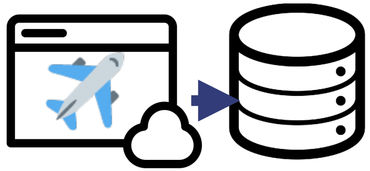
End Flight


```
{
  "Success": "true",
  "Confirmation Number": "789QPZ"
}
```


Done

Cancel Flight Request


```
{
  "Name": "Caitie McCaffrey",
  "Confirmation Number": "789QPZ"
}
```

End Comp Saga

Car

Hotel

Flight

Payment

Start Comp Saga

Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6KQ=="
}
```


Start Hotel

End Hotel


```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```


Start Flight

Start Car

Abort Car

Comp Hotel

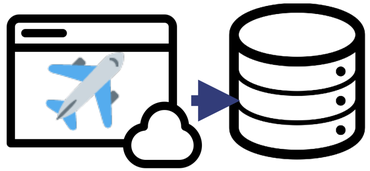
End Flight


```
{
  "Success": "true",
  "Confirmation Number": "789QPZ"
}
```


Comp Flight

Cancel Flight Response


```
{
  "Success": "true",
  "Confirmation Number": "789QPZ"
}
```

End Comp Saga

Car

Hotel

Flight

Payment

Start Comp Saga

Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6KQ=="
}
```


Start Hotel

End Hotel


```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```


Start Flight

Start Car

Abort Car

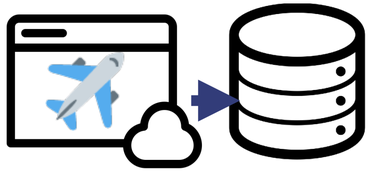
Comp Hotel

End Flight


```
{
  "Success": "true",
  "Confirmation Number": "789QPZ"
}
```


Comp Flight

Done



End Comp Saga

Car

Hotel

Flight

Payment

Start Comp Saga

Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6KQ=="
}
```


Start Hotel

End Hotel


```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```


Start Flight

Start Car

Abort Car

Comp Hotel

End Flight


```
{
  "Success": "true",
  "Confirmation Number": "789QPZ"
}
```


Comp Flight

End Saga

End Comp Saga

Car

Hotel

Flight

Payment

Start Comp Saga

Saga Log

Start Saga


```
{
  "Name": "Caitie McCaffrey",
  "Destination": "Malaga, Spain",
  "Start Date": "2017-05-17",
  "End Date": "2017-05-20",
  "Payment Token":
    "Tm90IG15IHJlYWwgY3JlZGl0IGNhcmQgaW5mbyA6KQ=="
}
```


Start Hotel

End Hotel


```
{
  "Success": "true",
  "Confirmation Number": "WXY123"
}
```


Start Flight

Start Car

Abort Car

Comp Hotel

End Flight


```
{
  "Success": "true",
  "Confirmation Number": "789QPZ"
}
```


Comp Flight

End Saga

Done

End Comp Saga

Car

Hotel

Flight

Payment

Start Comp Saga

Distributed Saga Guarantee

All requests were completed successfully

 Book Hotel  Book Car  Book Flight  Charge Money

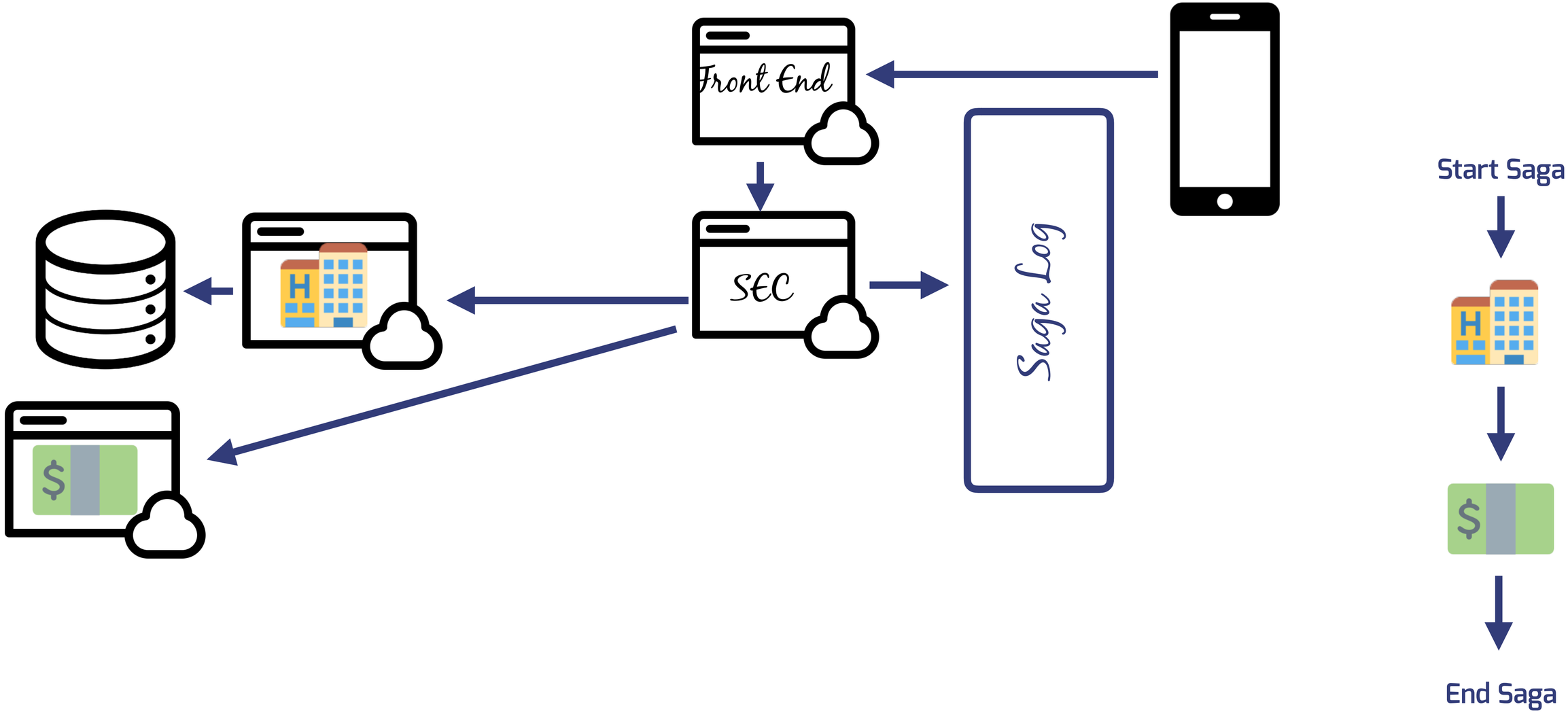
Or a subset of requests and the corresponding compensating requests were executed

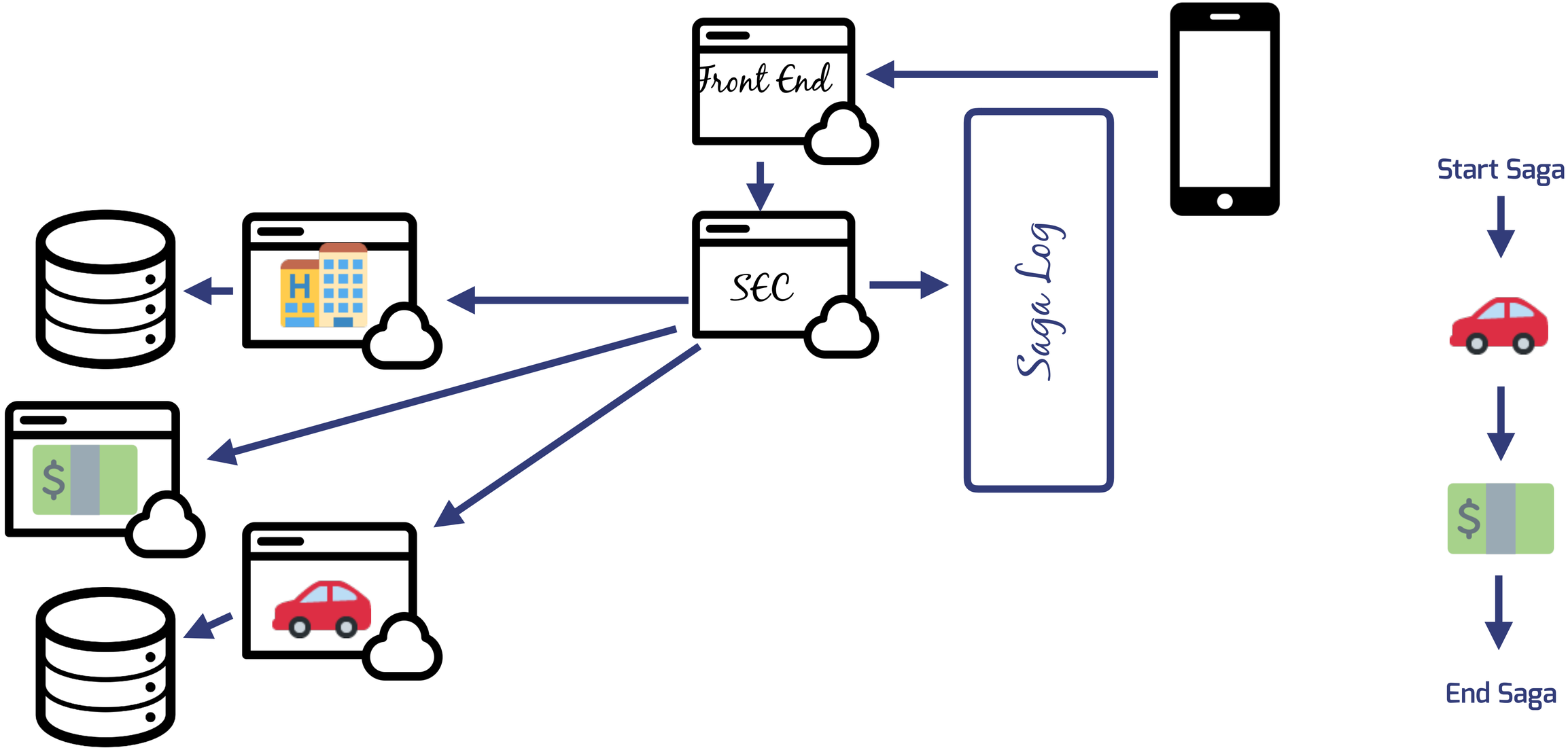
 Book Hotel  Book Car  Cancel Hotel  Cancel Car

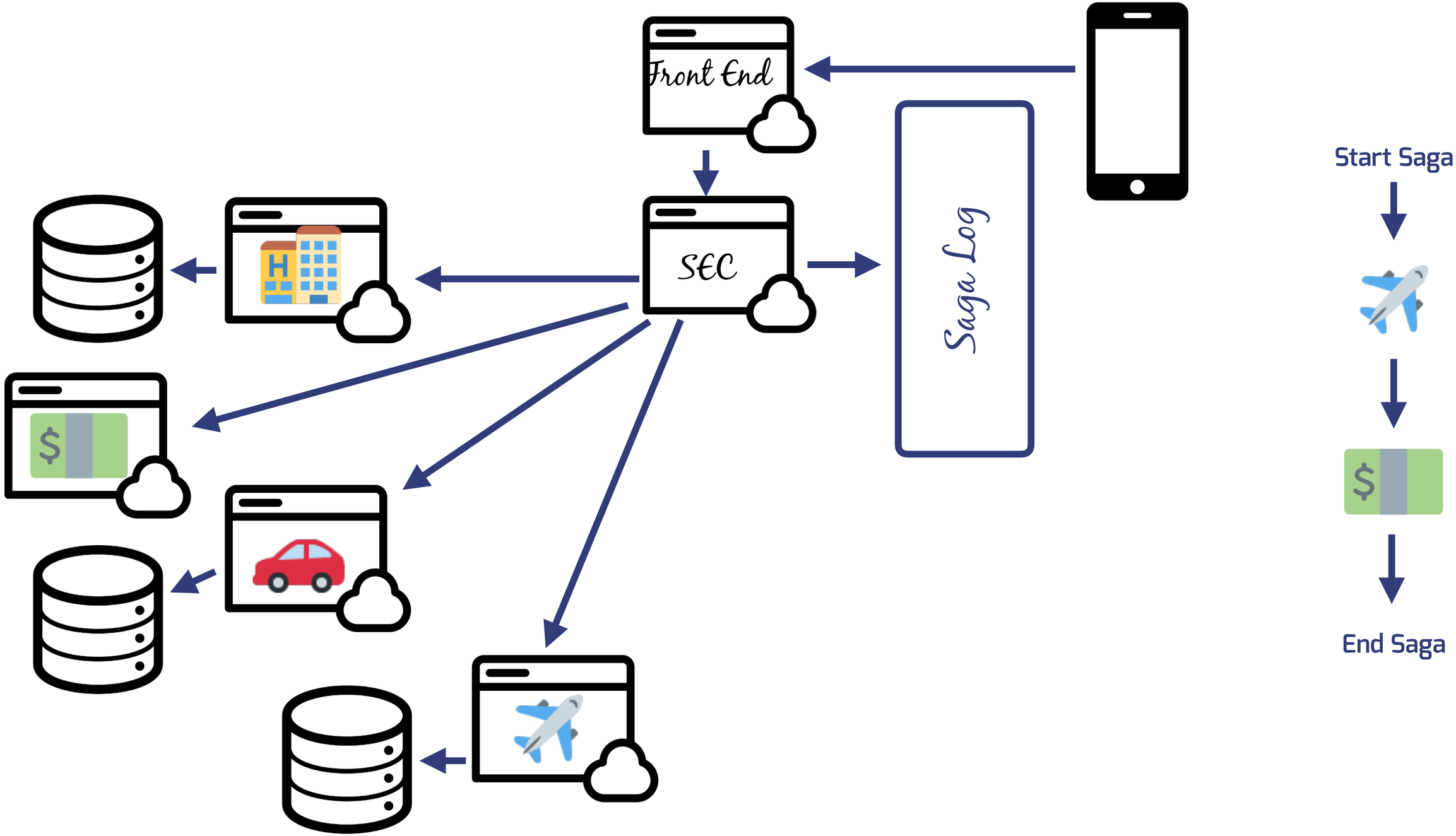
Recovering from

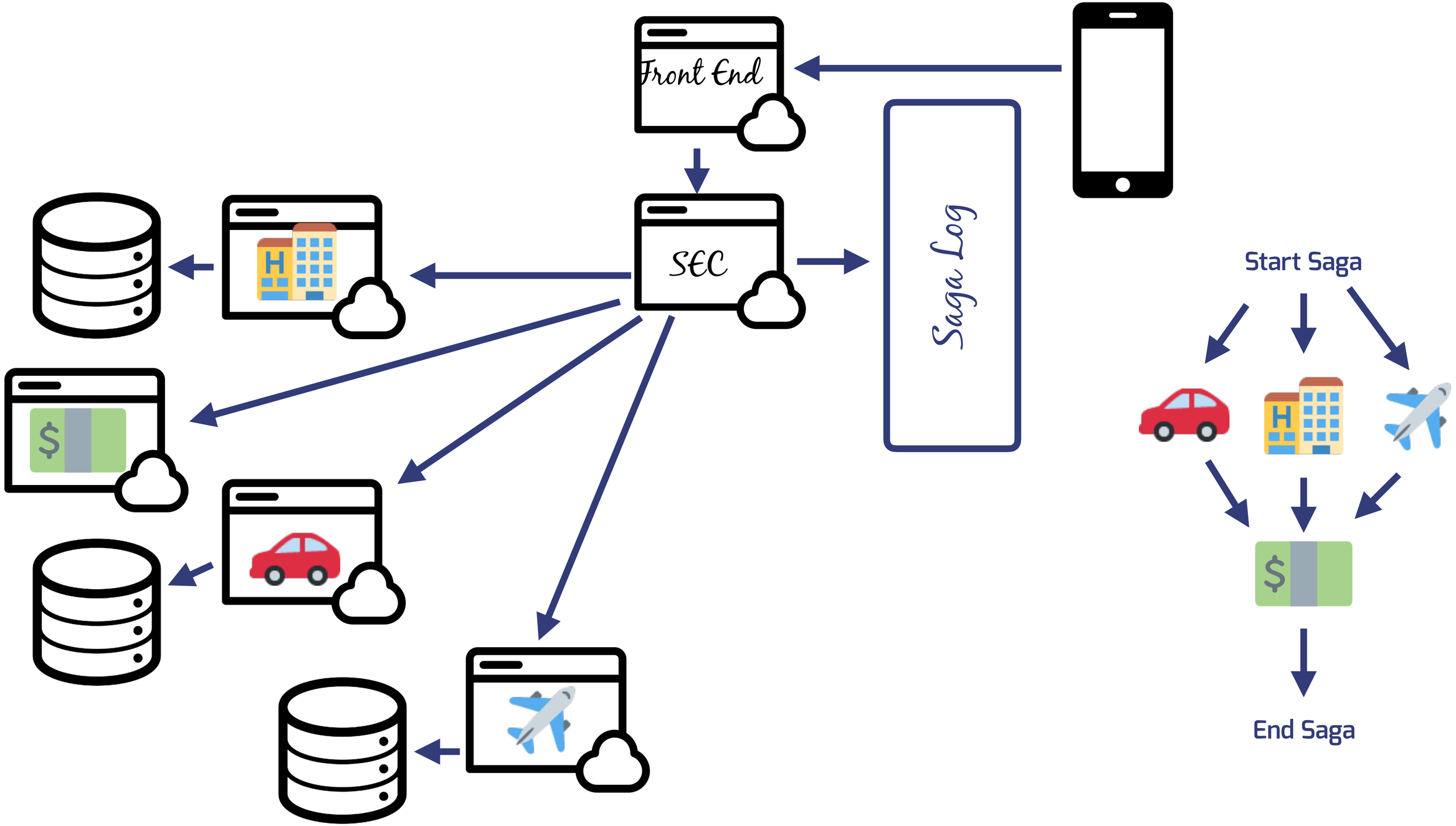
Saga Execution Coordinator

Failure


Front End
SEC
Saga Log
Start Saga
End Saga

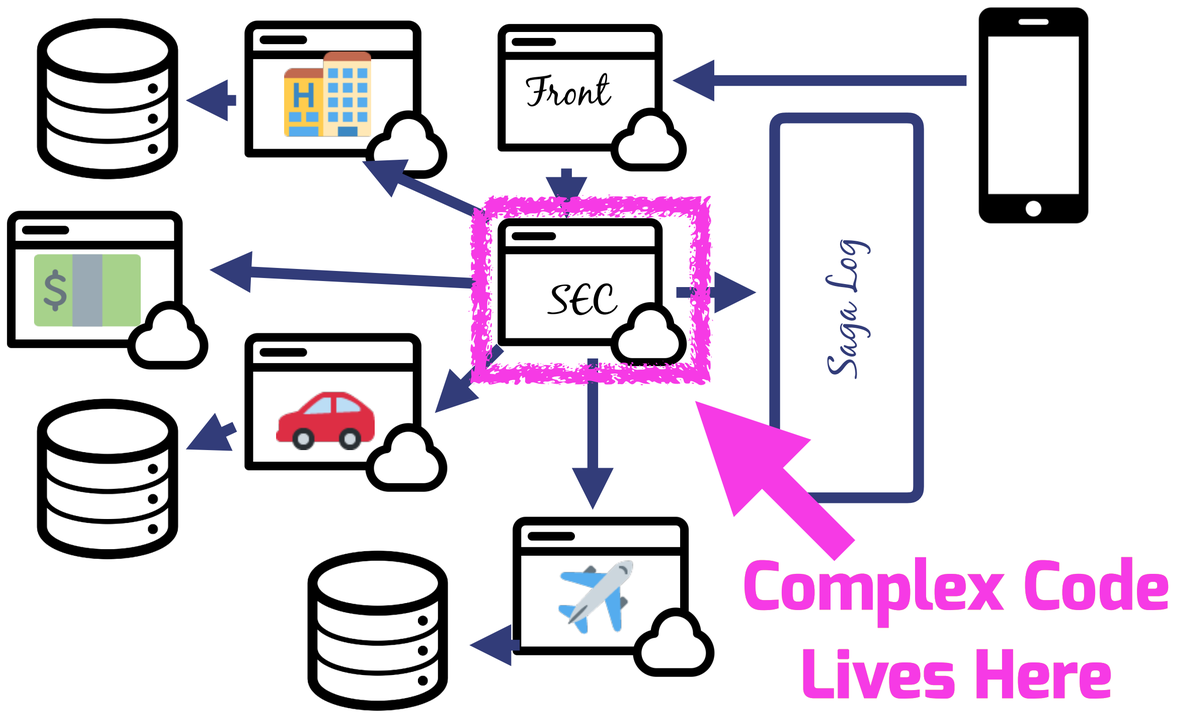

Front End
SEC
Saga Log
Start Saga
End Saga

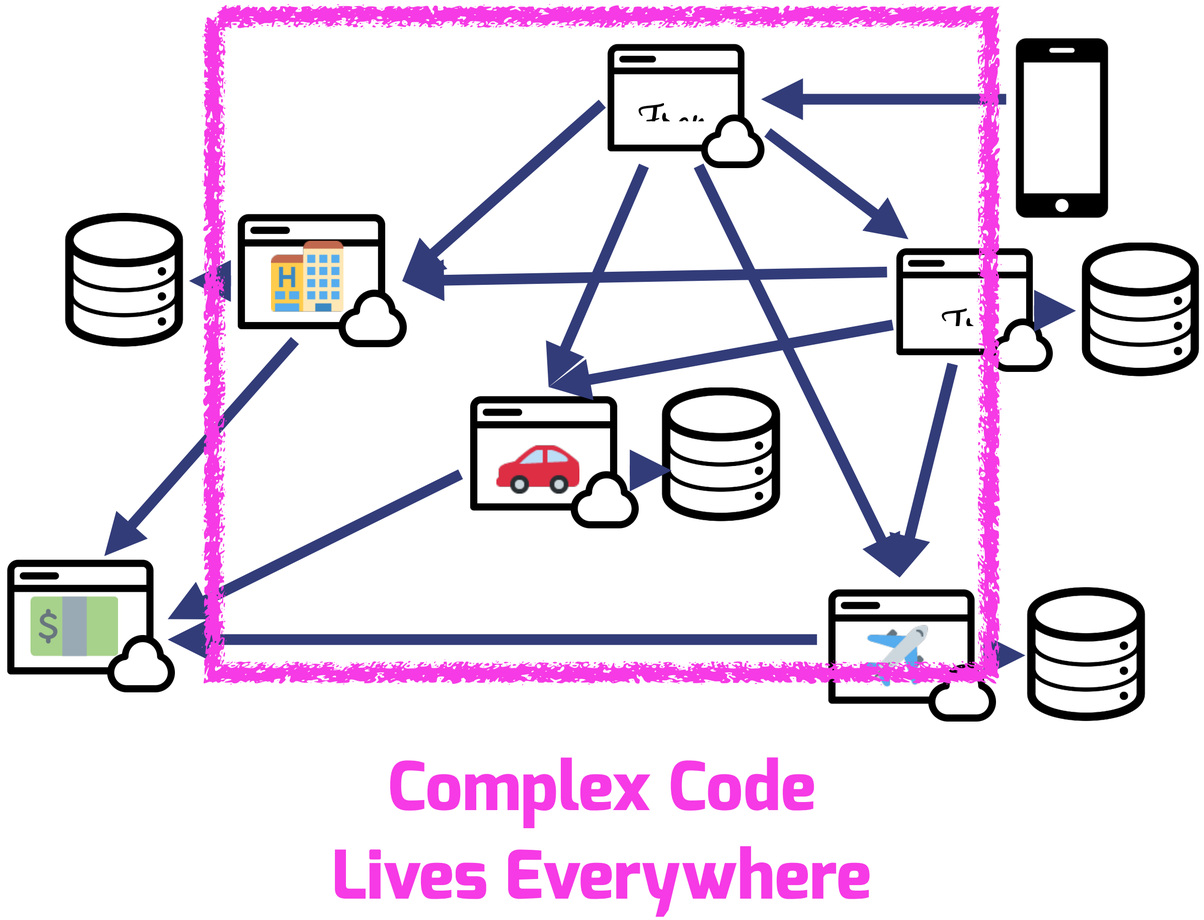

Front End
SEC
Saga Log
Start Saga
End Saga


Front End
SEC
Saga Log
Start Saga
End Saga

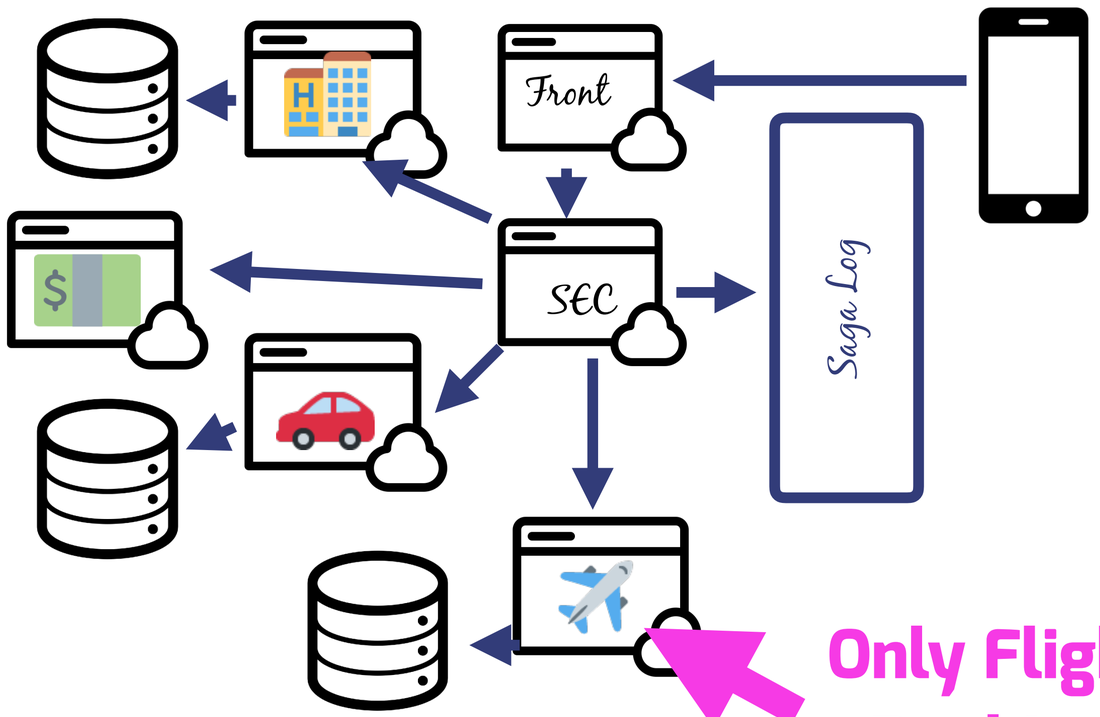
Isolation of Complex Code

with Distributed Sagas

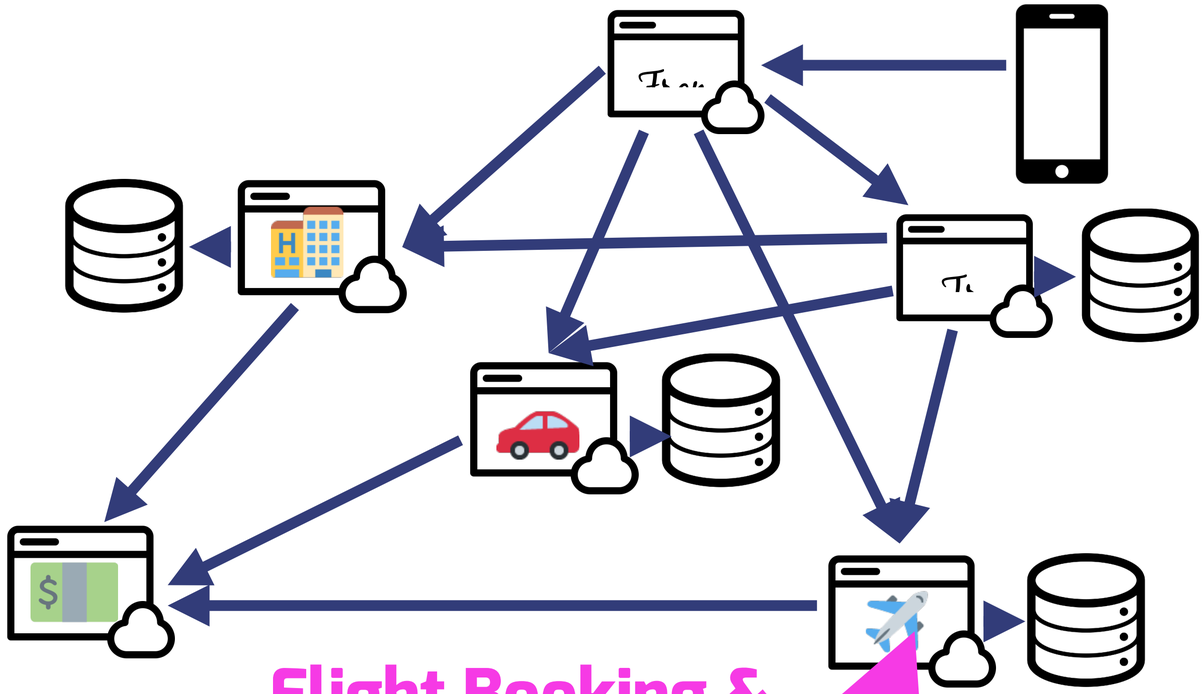




Modular Services
with Distributed Sagas

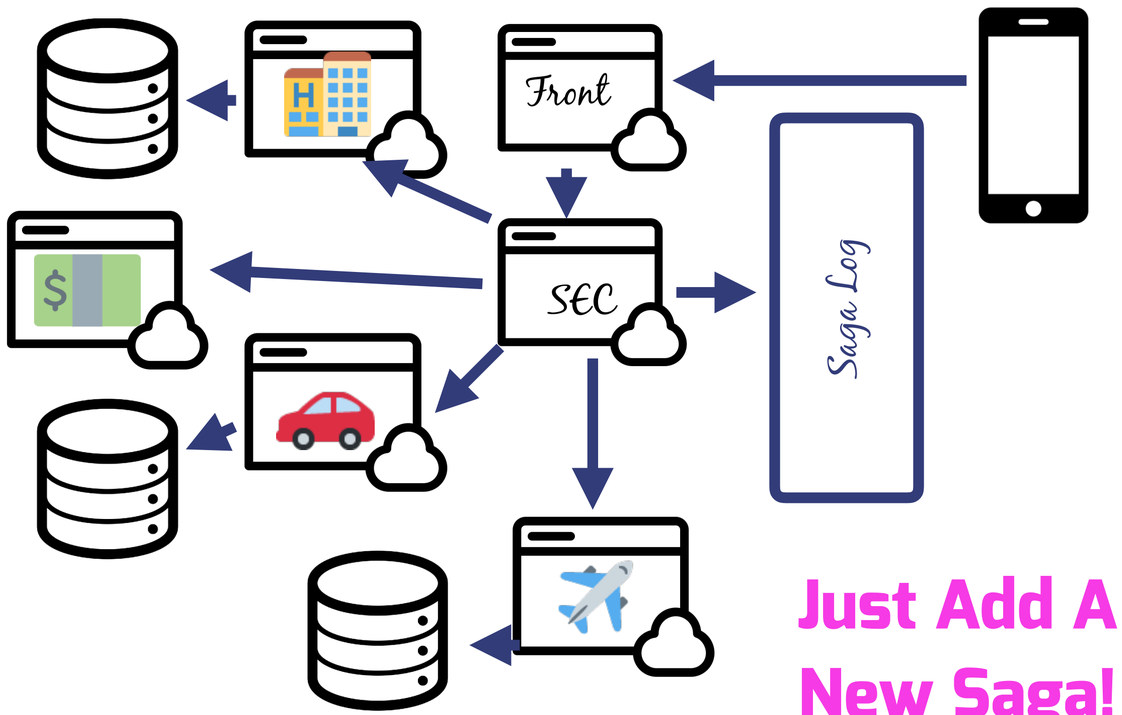


Only Flight Booking

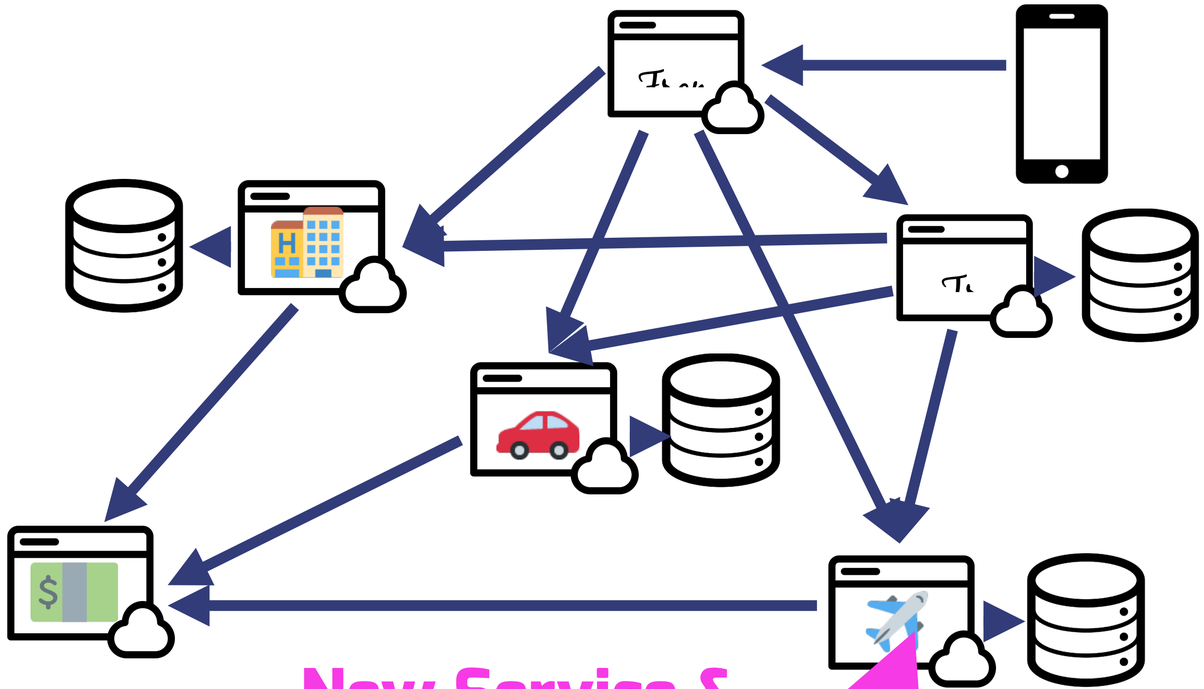


Flight Booking & Feral Concurrency Control Mechanisms

Service Composition
with Distributed Sagas



Just Add A New Saga!



New Service & Feral Concurrency Control Mechanisms

Distributed Sagas Makes Building & Modifying Microservices Easier

Thank you

@caitie