Shuffling: What it is and why it's important

Big Data Analysis with Scala and Spark

Heather Miller

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?? org.apache.spark.rdd.RDD[(String, Int)] = ShuffledRDD[366] ??
```

Think again what happens when you have to do a `groupBy` or a `groupByKey`. Remember our data is distributed! **Did you notice anything odd?**

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val pairs = sc.parallelize(List((1, "one"), (2, "two"), (3, "three")))
pairs.groupByKey()
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//    = ShuffledRDD[16] at groupByKey at <console>:37
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Shuffles Happen

Shuffles can be an enormous hit to because it means that Spark must send data from one node to another. Why? **Latency!**

Grouping and Reducing, Example

Let's start with an example. Given:

```
case class CFFPurchase(customerId: Int, destination: String, price: Double)
```

Assume we have an RDD of the purchases that users of the Swiss train company's, the CFF's, mobile app have made in the past month.

```
val purchasesRdd: RDD[CFFPurchase] = sc.textFile(...)
```

Goal: calculate how many trips, and how much money was spent by each individual customer over the course of the month.

Grouping and Reducing, Example

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val purchasesPerMonth = ...
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val purchasesPerMonth =
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              .groupByKey() // groupByKey returns RDD[K, Iterable[V]]
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Grouping and Reducing, Example

Goal: calculate how many trips, and how much money was spent by each individual customer over the course of the month.

```
val purchasesRdd: RDD[CFFPurchase] = sc.textFile(...)

// Returns: Array[(Int, (Int, Double))]
val purchasesPerMonth =
  purchasesRdd.map(p => (p.customerId, p.price)) // Pair RDD
              .groupByKey() // groupByKey returns RDD[(K, Iterable[V])]
              .map(p => (p._1, (p._2.size, p._2.sum)))
              .collect()
```

Grouping and Reducing, Example – What's Happening?

Let's start with an example dataset:

```
val purchases = List(CFFPurchase(100, "Geneva", 22.25),
                     CFFPurchase(300, "Zurich", 42.10),
                     CFFPurchase(100, "Fribourg", 12.40),
                     CFFPurchase(200, "St. Gallen", 8.20),
                     CFFPurchase(100, "Lucerne", 31.60),
                     CFFPurchase(300, "Basel", 16.20))
```

What might the cluster look like with this data distributed over it?

Grouping and Reducing, Example – What's Happening?

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Starting with `purchasesRdd`:

```
CFFPurchase(100, "Geneva", 22.25)
CFFPurchase(100, "Lucerne", 31.60)
```

```
CFFPurchase(100, "Fribourg", 12.40)
CFFPurchase(200, "St. Gallen", 8.20)
```

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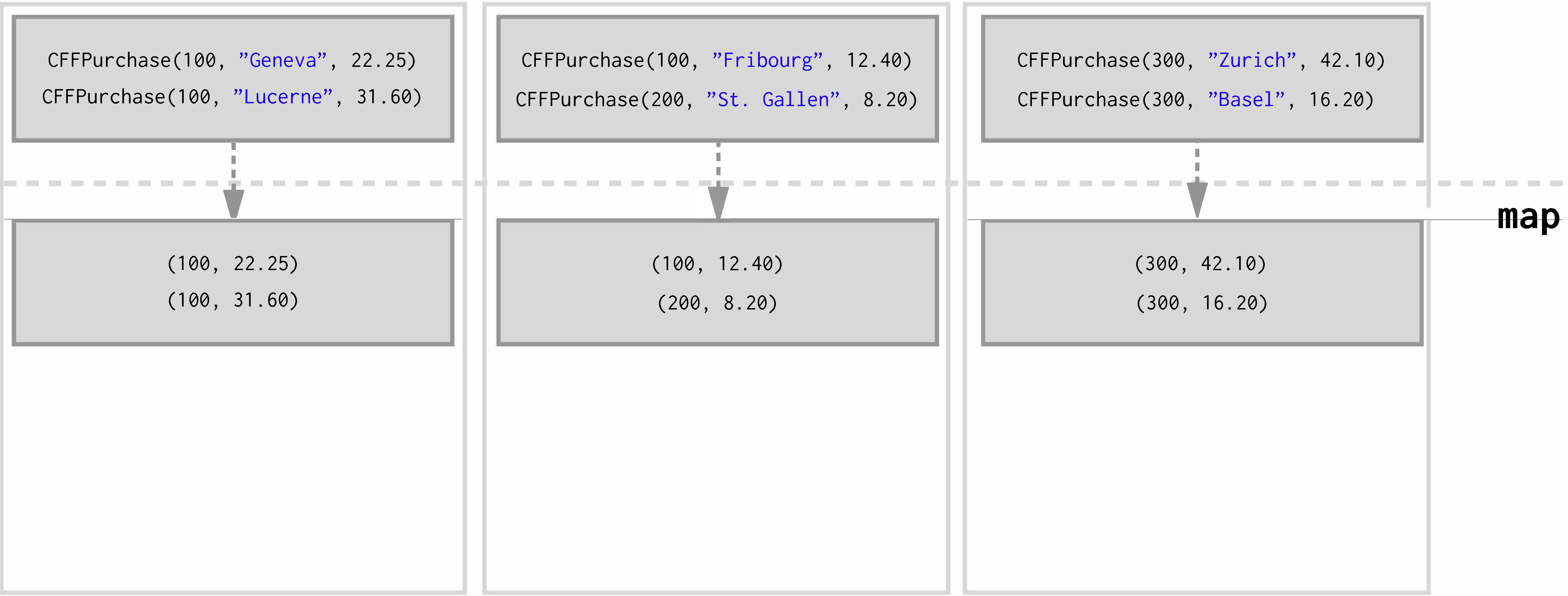
CFFPurchase(300, "Zurich", 42.10)
CFFPurchase(300, "Basel", 16.20)
```

Grouping and Reducing, Example – What's Happening?

What might this look like on the cluster?



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```

Note: groupByKey results in one key-value pair per key. And this single key-value pair cannot span across multiple worker nodes.

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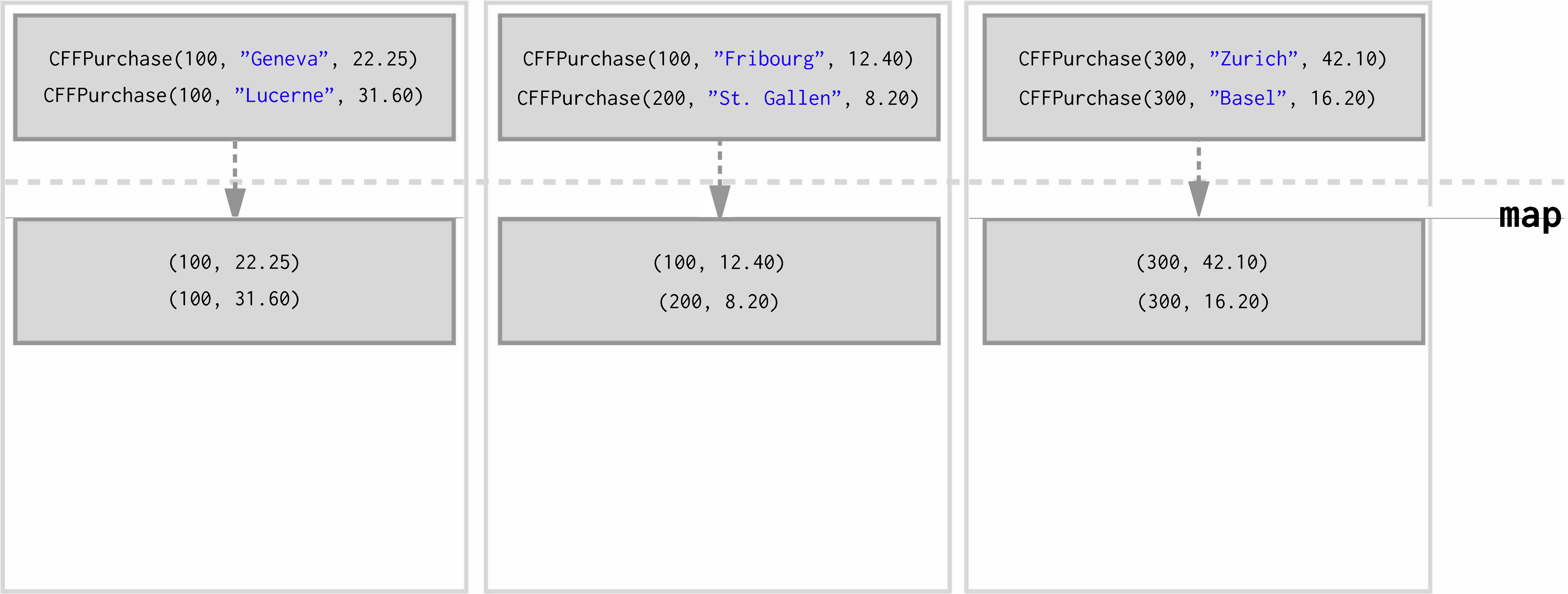

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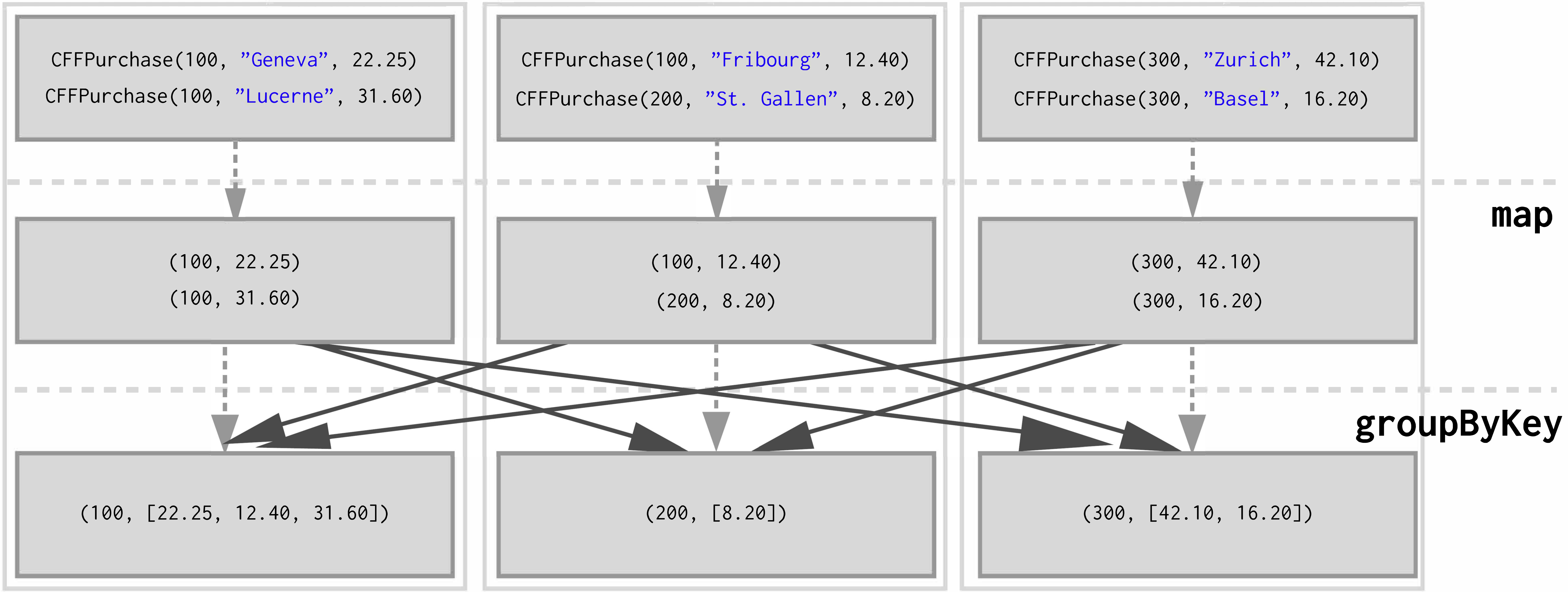

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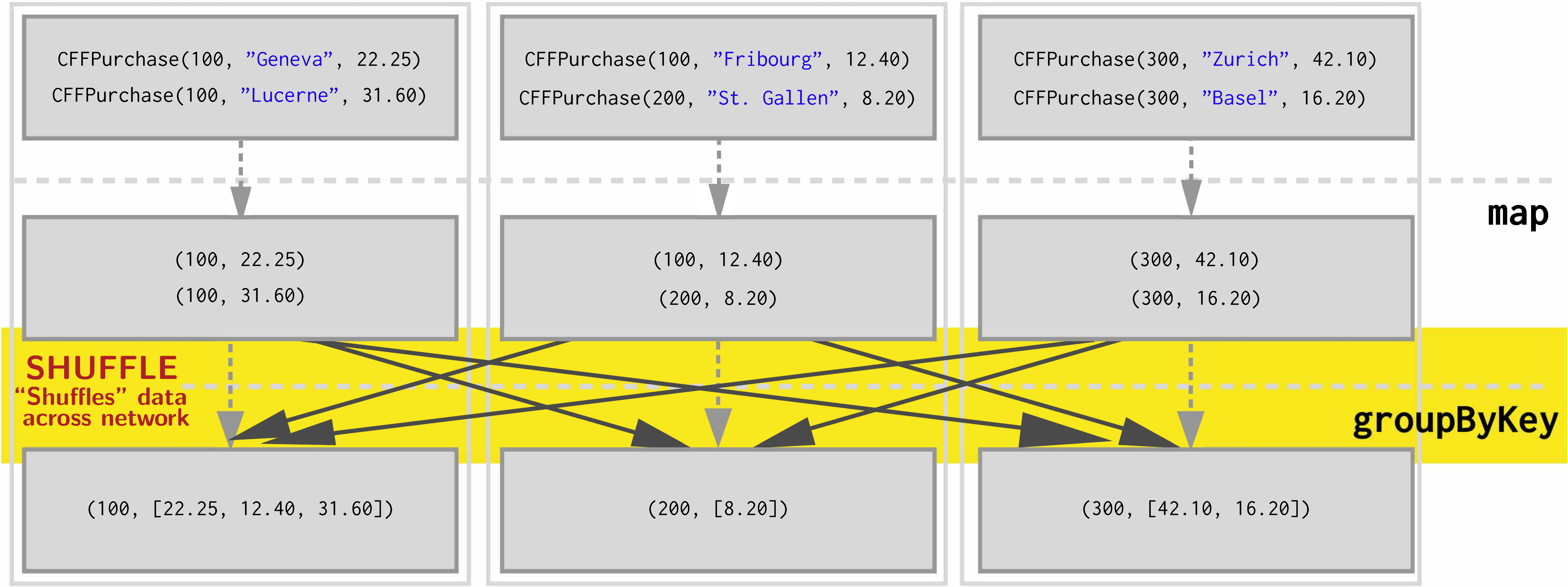

Reminder: Latency Matters (Humanized)

Shared Memory

Seconds

```
L1 cache reference..........0.5s
L2 cache reference............7s
Mutex lock/unlock...........25s
```

Minutes

```
Main memory reference.....1m 40s
```

Distributed

Days

```
Roundtrip within
same datacenter.........5.8 days
```

Years

```
Send packet
CA->Netherlands->CA....4.8 years
```

We don't want to be sending all of our data over the network if it's not absolutely required. Too much network communication kills performance.

Can we do a better job?

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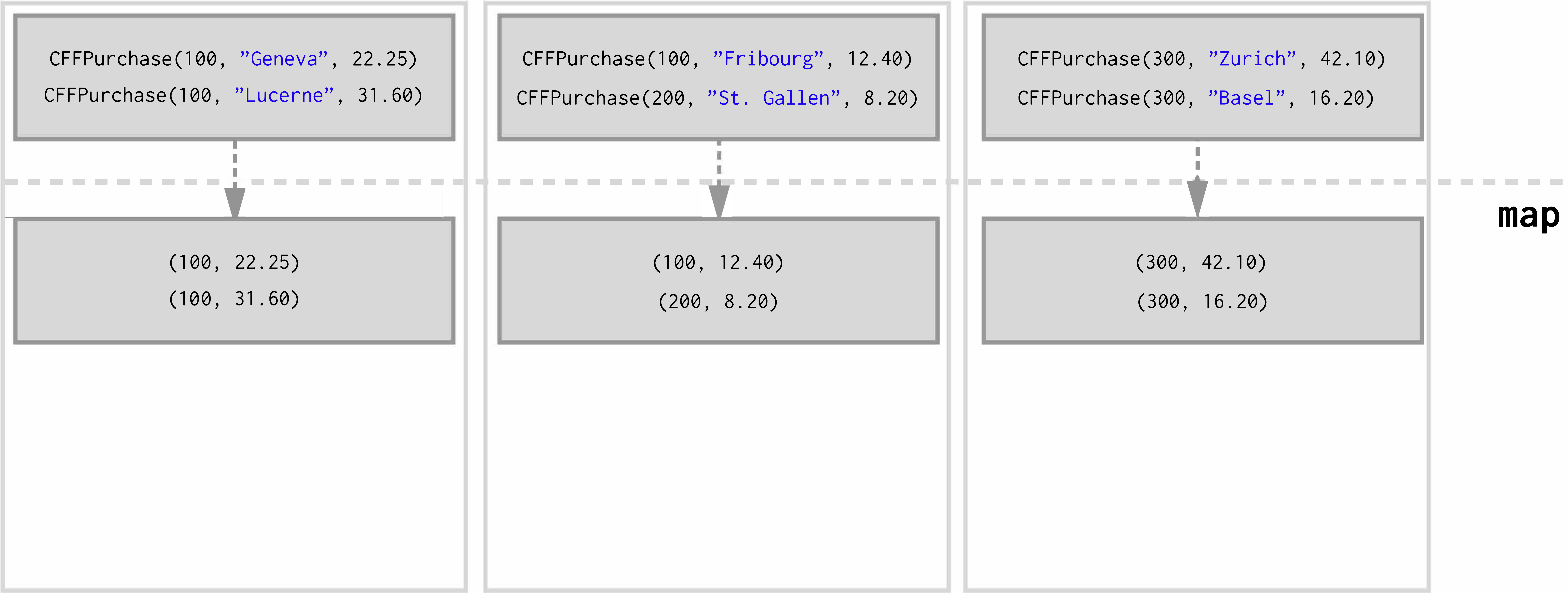

Perhaps we can reduce before we shuffle. This could greatly reduce the amount of data we have to send over the network.

Grouping and Reducing, Example – Optimized

We can use `reduceByKey`.

Conceptually, `reduceByKey` can be thought of as a combination of first doing `groupByKey` and then `reduce`-ing on all the values grouped per key. It's more efficient though, than using each separately. We'll see how in the following example.

Signature:

```
def reduceByKey(func: (V, V) => V): RDD[(K, V)]
```

Grouping and Reducing, Example – Optimized

Goal: calculate how many trips, and how much money was spent by each individual customer over the course of the month.

```
val purchasesRdd: RDD[CFFPurchase] = sc.textFile(...)

val purchasesPerMonth =
  purchasesRdd.map(p => (p.customerId, (1, p.price))) // Pair RDD
              .reduceByKey(...) // ?
```

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val purchasesRdd: RDD[CFFPurchase] = sc.textFile(...)

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```

Notice that the function passed to `map` *has changed. It's now* `p => (p.customerId, (1, p.price))`*.*

What function do we pass to `reduceByKey` in order to get a result that looks like: `(customerId, (numTrips, totalSpent))` returned?

Grouping and Reducing, Example – Optimized

```
val purchasesPerMonth =
  purchasesRdd.map(p => (p.customerId, (1, p.price))) // Pair RDD
                .reduceByKey(...) // ?
```

(Int, Double)

Grouping and Reducing, Example – Optimized

```
val purchasesPerMonth =
  purchasesRdd.map(p => (p.customerId, (1, p.price))) // Pair RDD
              .reduceByKey((v1, v2) => (v1._1 + v2._1, v1._2 + v2._2))
              .collect()
```

1+1   price+price

Grouping and Reducing, Example – Optimized

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val purchasesPerMonth =
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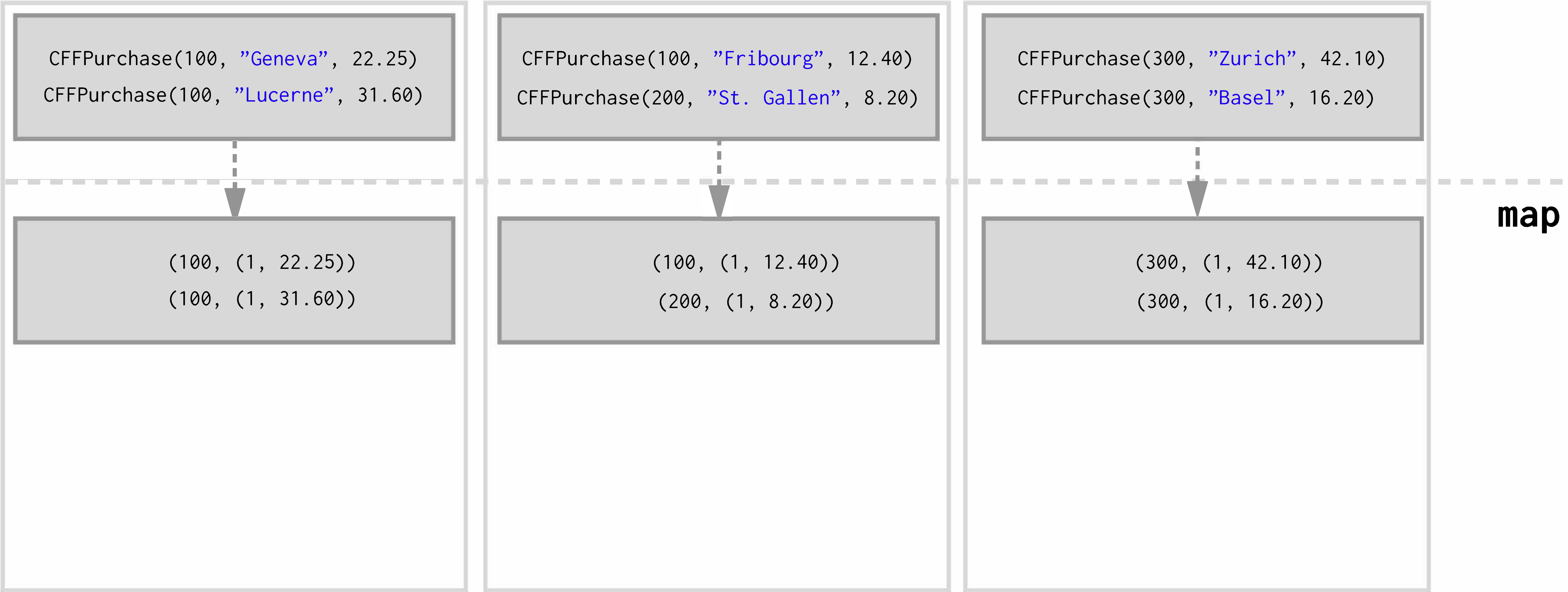

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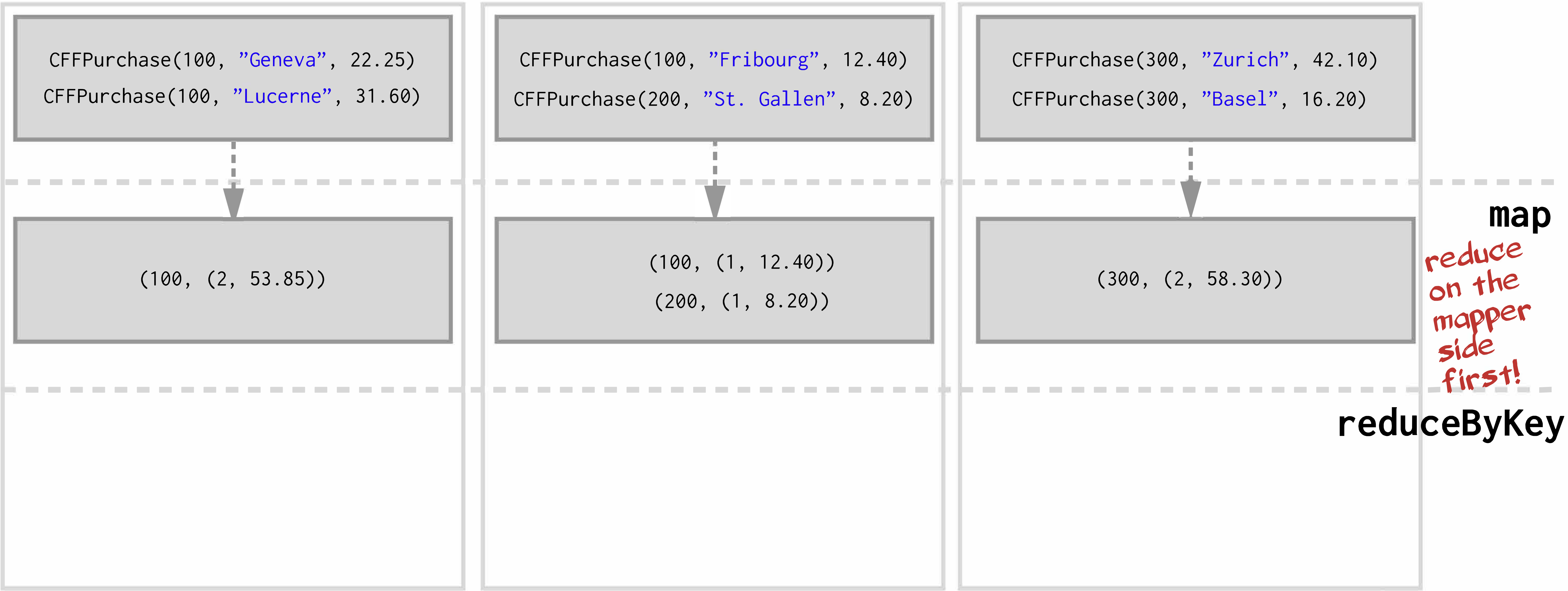

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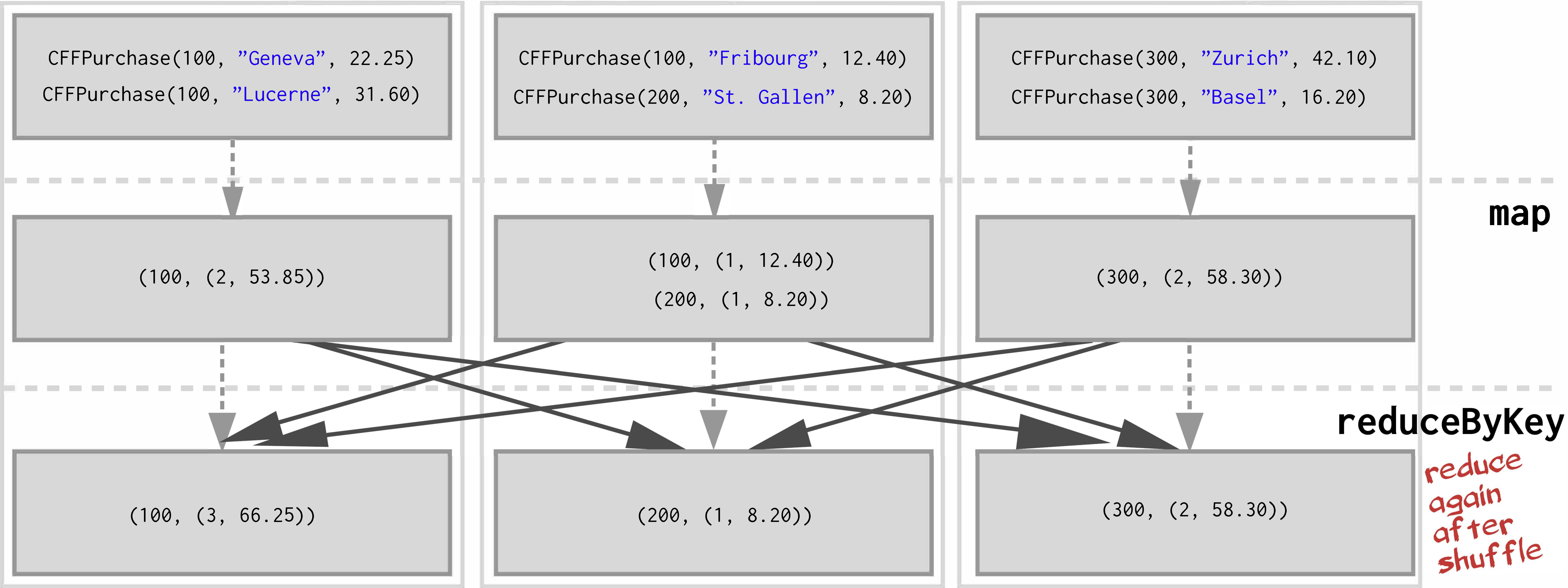

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Let's benchmark on a real cluster.

groupByKey and reduceByKey Running Times

```
> val purchasesPerMonthSlowLarge = purchasesRddLarge.map(p => (p.customerId, p.price))
                                                    .groupByKey()
                                                    .map(p => (p._1, (p._2.size, p._2.sum)))
                                                    .count()

  purchasesPerMonthSlowLarge: Long = 100000
  Command took 15.48s
```

```
> val purchasesPerMonthFastLarge = purchasesRddLarge.map(p => (p.customerId, (1, p.price)))
                                                    .reduceByKey((v1, v2) => (v1._1 + v2._1, v1._2 + v2._2))
                                                    .count()

  purchasesPerMonthFastLarge: Long = 100000
  Command took 4.65s
```

Shuffling

Recall our example using groupByKey:

```
val purchasesPerCust =
  purchasesRdd.map(p => (p.customerId, p.price)) // Pair RDD
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Grouping all values of key-value pairs with the same key requires collecting all key-value pairs with the same key on the same machine.

But how does Spark know which key to put on which machine?

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But how does Spark know which key to put on which machine?

- By default, Spark uses *hash partitioning* to determine which key-value pair should be sent to which machine.