

Heimdall

A Privacy-Respecting Implicit Preference Collection Framework

Amir Rahmati, Earlence Fernandes,
Kevin Eykholt, Xinheng Chen, Atul Prakash





We know just the place.

Allow "Yelp" to access your location while you use the app?

This app needs your location to search for nearby businesses.

Don't Allow

Allow

Get Started!

Already have a Yelp account?

Log In

SOFTpedia

Log In

SOFTpedia

Privacy policy | Terms of service | Help

Help



We know just the place.

Allow "Yelp" to access your location while you use the app?

This app needs your location to search for nearby businesses.

Don't Allow

Allow

Get Started!

Already have a Yelp account?

Log In

SOFTpedia

Log In

Already have a saved Yelp account?

Get Started

Verizon LTE 5:08 PM 36%

Filter Restaurants Current Map Area Map

Price *** Open Now Good for Dinner Good for

1. Terry B's 1 mi
4.7 Reviews 47 Reviews
7854 Ann Arbor St, Dexter
American (New), Bars

Down W. "Terry B's is great new American fare. An intimate, comfortably modern small restaurant in the heart of charm..."

2. Riverview Cafe Restaurant 0.9 mi
4.5 Reviews 23 Reviews
8124 Main St, Dexter
Breakfast & Brunch, Diners

Megan K. "The service! The food! The owner! Loved our whole experience. The waitress was really nice, she even came b..."

3. Hotel Hickman Chuck Wagon 1.0 mi
BBQ 4.1 Reviews 41 Reviews
8060 Main St, Dexter
Barbecue

L.A. "Opens Thursday to Sunday. They close earlier. Grab a slab with all the fixin to feed 2 to 3 people with all the fixi..."

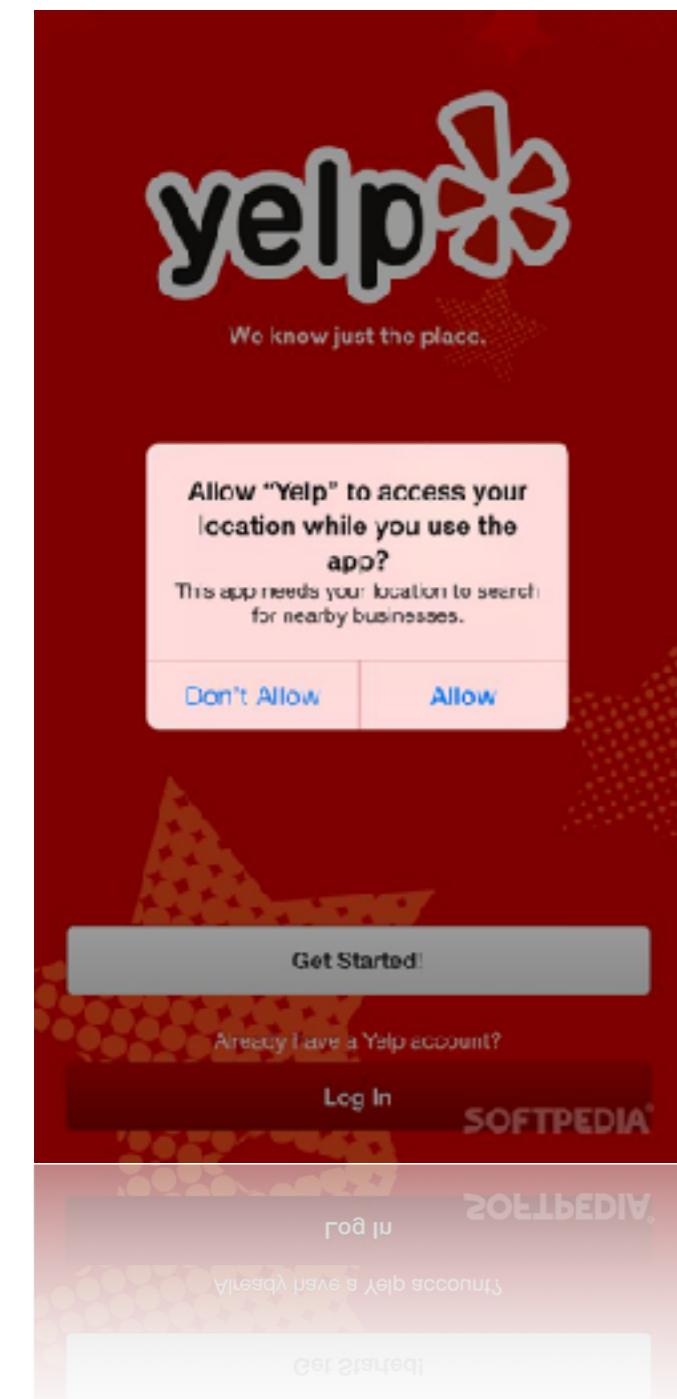
4. Red Brick Kitchen & Bar 1.0 mi
4.5 Reviews 122 Reviews
8033 Main St, Dexter
American (New)

Anne S. "We had a double date here Saturday night with friends, and I was quite impressed. I thought everything ..."

Nearby Search YelpNearby Activity More
YelpNearby Search YelpNearby Activity More
YelpNearby Search YelpNearby Activity More

"... building every day throughout the season. It's been a great year for us, and we're looking forward to another great year next year."



The screenshot shows the Yelp mobile application's search results screen. At the top, there is a header with signal strength, time (5:08 PM), battery level (36%), and a "Cancel" button. The main title is "Terry B's" with a "Check In" button. Below the header is a text input field with the placeholder "Add a comment (e.g. 'Hanging out with friends!')".

Verizon LTE 5:08 PM 36% ■

Cancel Terry B's Check In

Add a comment (e.g. "Hanging out with friends!")

SHARE WITH FRIENDS ON

yelp twitter facebook

Check In

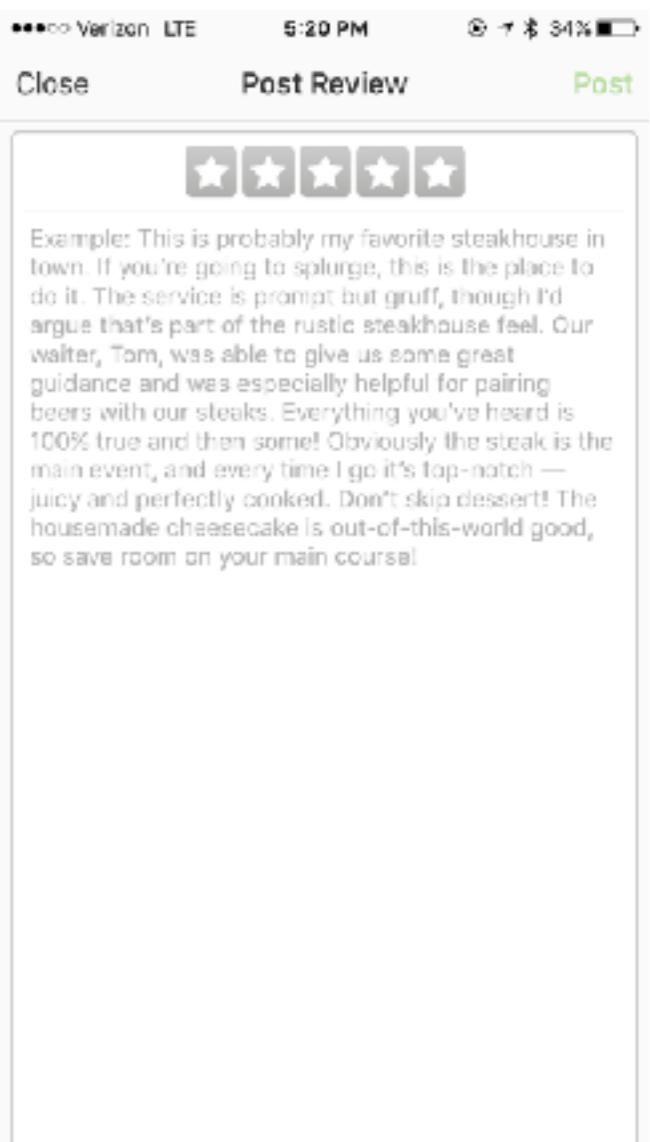
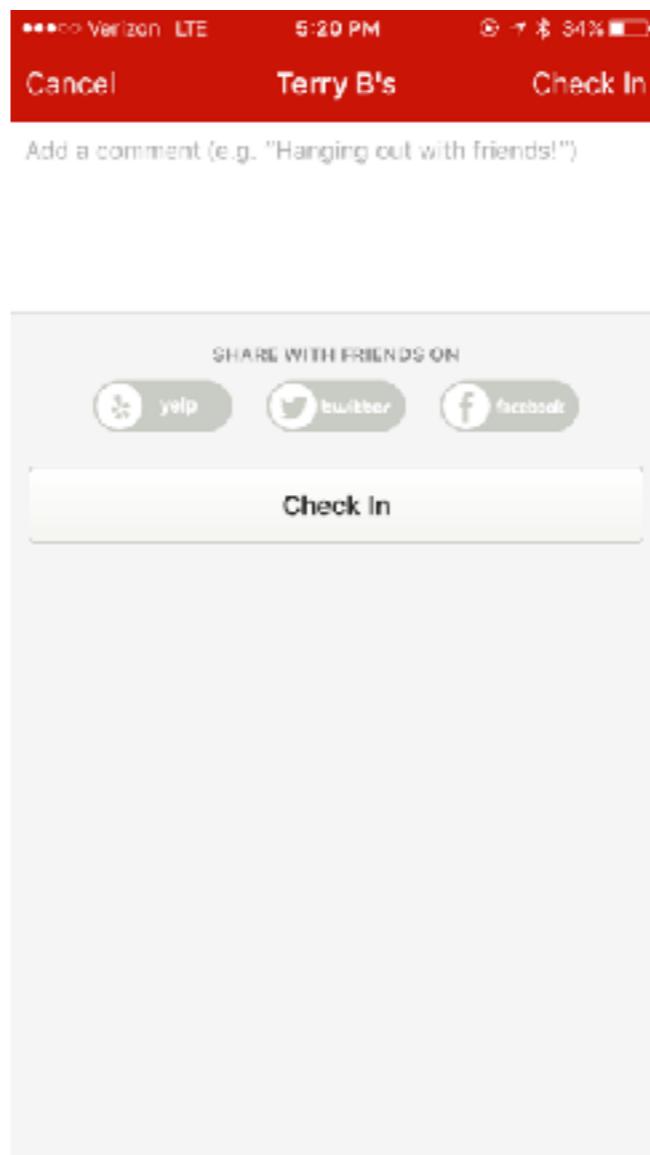
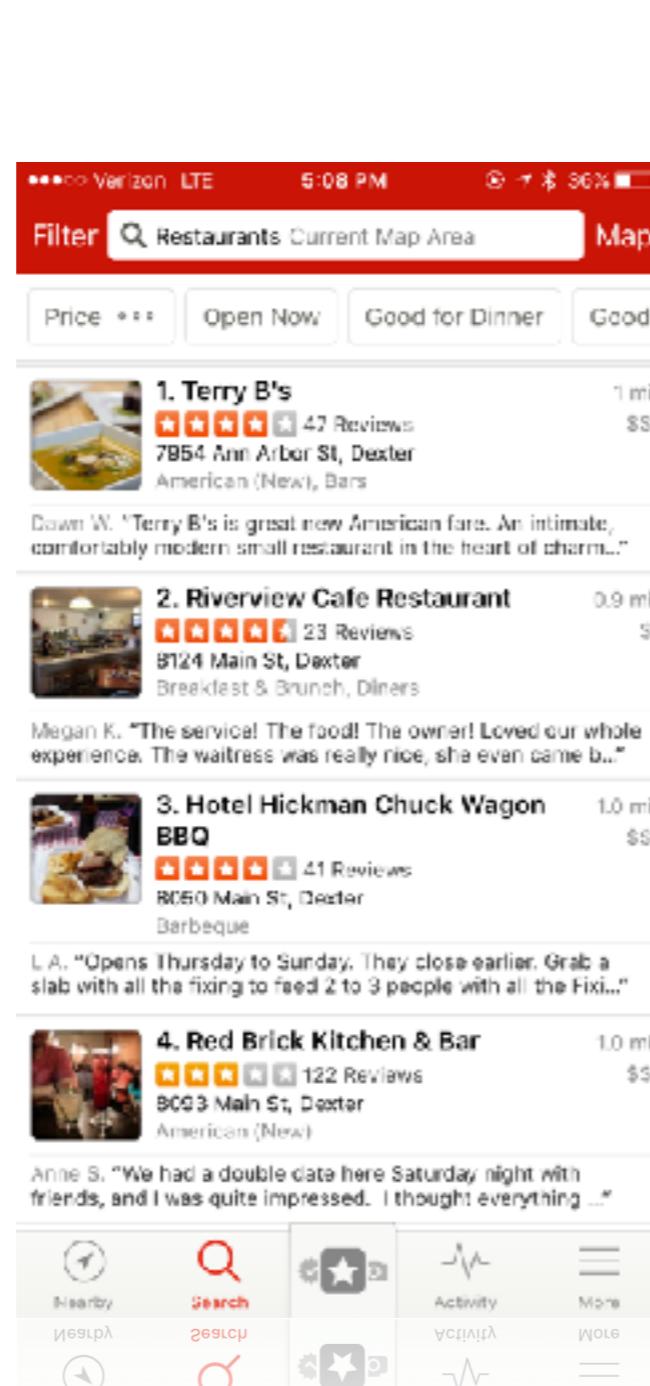
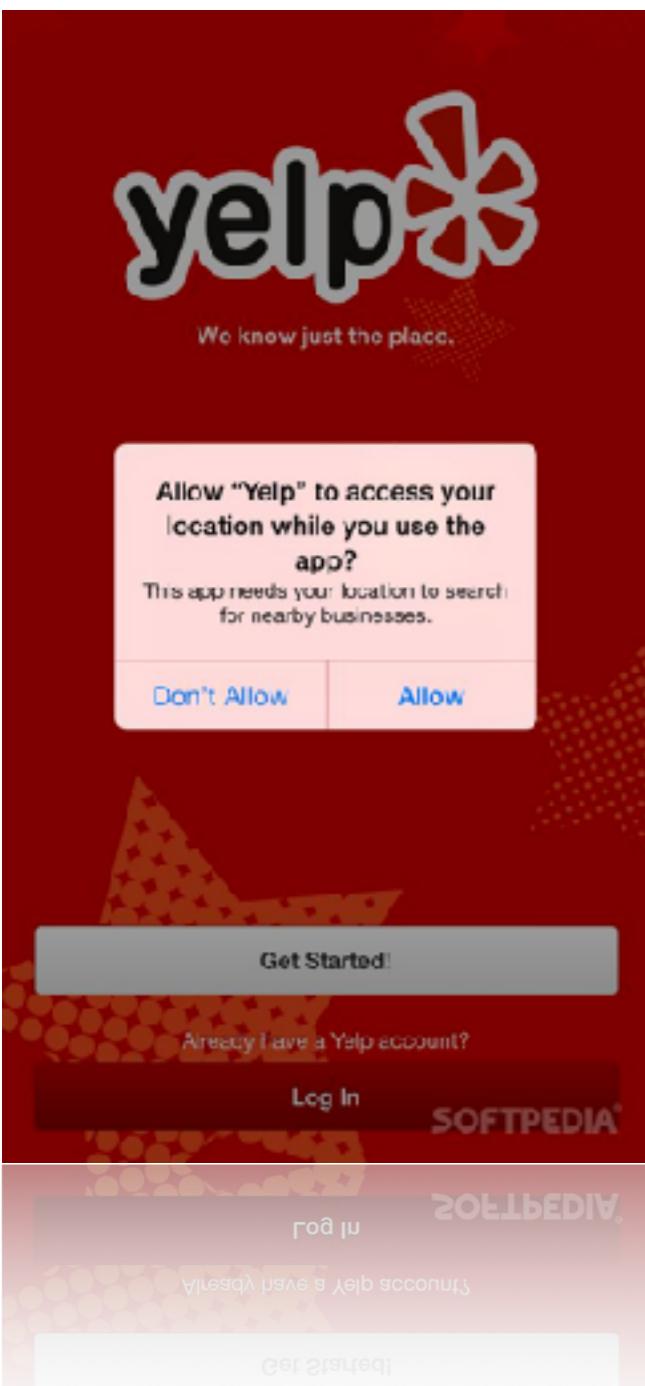
Rank	Business Name	Address	Distance	Avg. Review Score	Review Count	Category
1.	Terry B's	7854 Ann Arbor St, Dexter	1 mi	4.5	47 Reviews	American (New), Bars
2.	Riverview Cafe Restaurant	8124 Main St, Dexter	0.9 mi	4.5	23 Reviews	Breakfast & Brunch, Diners
3.	Hotel Hickman Chuck Wagon	8060 Main St, Dexter	1.0 mi	4.5	41 Reviews	Barbecue
4.	Red Brick Kitchen & Bar	8033 Main St, Dexter	1.0 mi	4.5	122 Reviews	American (New)

Megan K. "The service! The food! The owner! Loved our whole experience. The waitress was really nice, she even came b..."

L.A. "Opens Thursday to Sunday. They close earlier. Grab a slab with all the fixin to feed 2 to 3 people with all the fixi..."

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At the bottom of the screen is a navigation bar with icons for Nearby, Search, YelpNear, Activity, More, and a footer with social media links for Facebook, Twitter, and Yelp.



•••oo Verizon LTE 5:08 PM 36%

Filter Restaurants Current Map Area

Price Open Now Good for Dinner Good for...

1. Terry B's 1 mi
★★★★★ 47 Reviews \$\$
7954 Ann Arbor St, Dexter
American (New), Bars

Dawn W. "Terry B's is great new American fare. An intimate, comfortably modern small restaurant in the heart of charm..."

2. Riverview Cafe Restaurant 0.9 mi
★★★★★ 23 Reviews \$
8124 Main St, Dexter
Breakfast & Brunch, Diners

Megan K. "The service! The food! The owner! Loved our whole experience. The waitress was really nice, she even came b..."

3. Hotel Hickman Chuck Wagon 1.0 mi
BBQ \$\$
★★★★★ 41 Reviews
8050 Main St, Dexter
Barbecue

L.A. "Opens Thursday to Sunday. They close earlier. Grab a slab with all the fixin to feed 2 to 3 people with all the fixi..."

4. Red Brick Kitchen & Bar 1.0 mi
★★★★★ 122 Reviews \$\$
8093 Main St, Dexter
American (New)

Anne S. "We had a double date here Saturday night with friends, and I was quite impressed. I thought everything..."

Nearby Search Favorites Activity More

Nearby Search Favorites Activity More

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(ven) nesnma
Dexter, MI 48130 USA
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•••oo Verizon LTE 5:08 PM 36%

Filter Restaurants Current Map Area Map

Price Open Now Good for Dinner Good for

1. Terry B's 1 mi
47 Reviews
7954 Ann Arbor St, Dexter
American (New) Cuisine

Dawn W. "Terry B's is great new American fare. An intimate, comfortably modern small restaurant in the heart of charm..."

2. Riverview Cafe Restaurant 0.9 mi
23 Reviews
8124 Main St, Dexter
Breakfast & Brunch, Chinese

Megan K. "The service! The food! The owner! Loved our whole experience. The waitress was really nice, she even came b..."

3. Hotel Hickman Chuck Wagon 1.0 mi
41 Reviews
8050 Main St, Dexter
Barbecue

L.A. "Opens Thursday to Sunday. They close earlier. Grab a slab with all the fixin to feed 2 to 3 people with all the fixi..."

4. Red Brick Kitchen & Bar 1.0 mi
122 Reviews
8093 Main St, Dexter
American (New) Cuisine

Anne B. "We had a double date here Saturday night with friends, and I was quite impressed. I thought everything..."

Nearby Search Activity More
Nearby Search Activity More
Nearby Search Activity More

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[redacted] (ven) nesicma
Dexter, MI 48130

Filter Restaurants Current Map Area

Price Open Now Good for Dinner Good for...

1. Terry B's 47 Reviews 1 mi \$\$\$
7954 Ann Arbor St, Dexter
American (New) Fare

Dawn W. "Terry B's is great new American fare. An intimate, comfortably modern small restaurant in the heart of charm..."

2. Riverview Cafe Restaurant 23 Reviews 0.9 mi \$\$
8124 Main St, Dexter
Breakfast & Brunch, Diners

Megan K. "The service! The food! The owner! Loved our whole experience. The waitress was really nice, she even came b..."

3. Hotel Hickman Chuck Wagon BBQ 41 Reviews 1.0 mi \$\$\$
8050 Main St, Dexter
Barbecue

L.A. "Opens Thursday to Sunday. They close earlier. Grab a slab with all the fixin to feed 2 to 3 people with all the fixi..."

4. Red Brick Kitchen & Bar 122 Reviews 1.0 mi \$\$
8093 Main St, Dexter
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Anne S. "We had a double date here Saturday night with friends, and I was quite impressed. I thought everything ..."

Nearby Search Check-in Activity More

Nearby Search Check-in Activity More

Filter Restaurants Current Map Area

12. Mug & Bopps 1.3 mi
★ ★ ★ ★ 3 Reviews \$
2940 Baker Rd, Dexter
Pizza, Convenience Store, Car Wash

B.B. "I go here a lot and the reason I can rate 5 stars is because there is such great prices on stuff here and so many options..."

13. Classic Pizza 0.9 mi
★★★★ 13 Reviews \$\$
8015 Huron St, Ste A, Dexter
Pizza

[Order Pickup or Delivery](#)

14. Alpha Coney Island 2 mi
★★★★ 14 Reviews \$
7049 Dexter Ann Arbor Rd, Dexter
American (Traditional), Coney

A.M. "Stopped in to grab a quick breakfast after bicycling on the new Dexter bike trail on a sunny Saturday morning and..."

15. Cottage Inn Pizza 0.9 mi
★★★★ 14 Reviews \$
3219 Broad St, Ste 1, Dexter
Pizza

Karen N. "Rude on the phone. Almost hung up but I want my pizza. This guy is not loving his job and it shows"

16. Jet's Pizza 2 mi
★★★★ 4 Reviews \$
7011 Dexter Ann Arbor Rd, Dexter
Pizza

Nearby Search Favorites Activity More
 Address Gender Settings Vibration List
 Buzzer Swiggy Zomato Delivery Map

State of the Art

State of the Art

- Rely on User Interaction and Feedback
 - Interaction Requirement
 - Data Sparsity

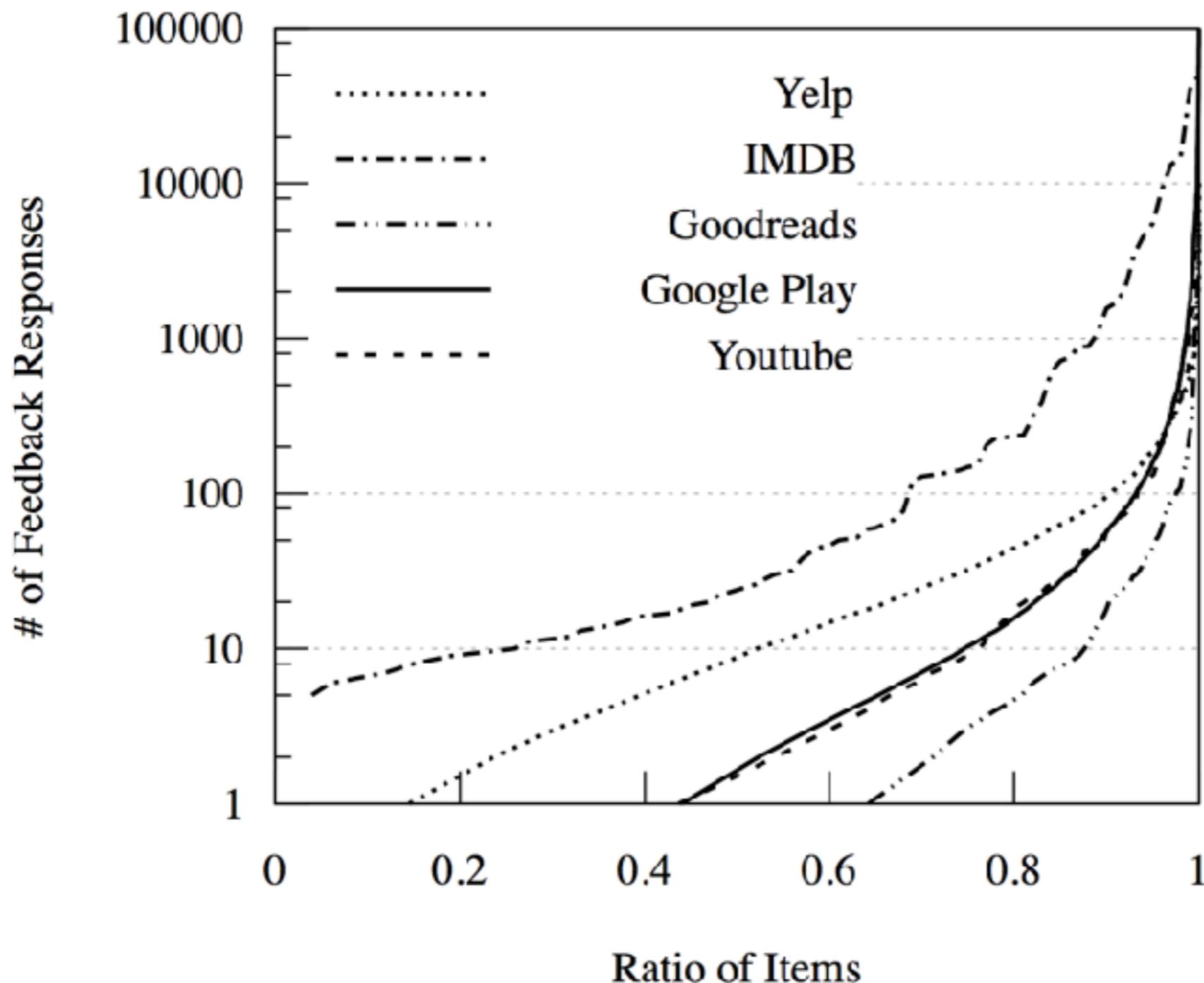
State of the Art

- Rely on User Interaction and Feedback
 - Interaction Requirement
 - Data Sparsity
- Coarse-grained Collection
 - Privacy Concerns

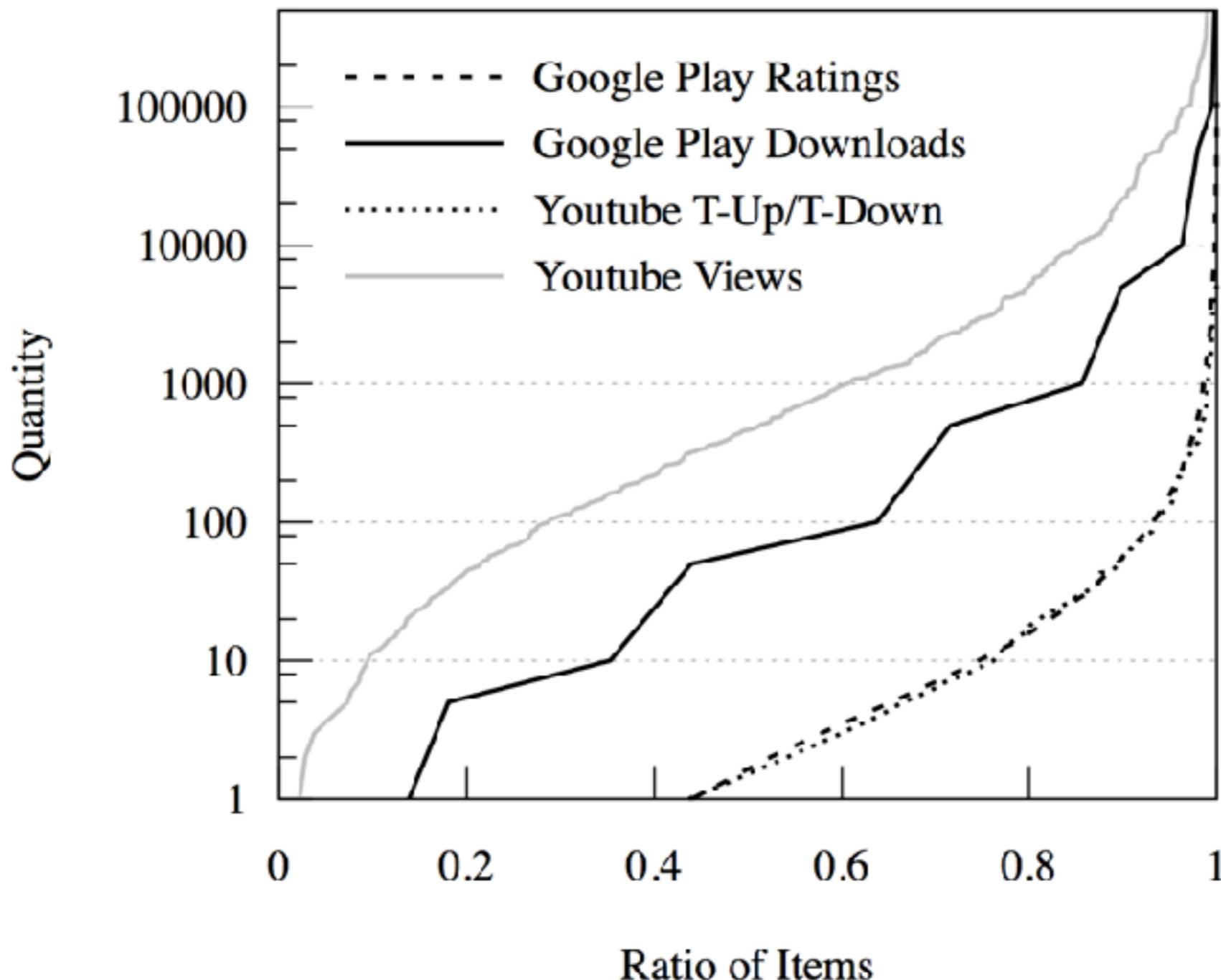
Measurement Study

Source	Type	# of Samples	Definition of Interaction
Goodreads	Books	500	Rating (1-5 stars)
Yelp	Restaurants	10,000	Rating (1-5 stars)
Google Play	Applications	10,000	Rating (1-5 stars)
IMDB	Movies	500	Rating (0.5-5 stars)
Youtube	Videos	500	Up/down vote

Data Sparsity



Discrepancy Between Utilization and Feedback



Allow Privacy-Respecting
Fine-Grained Data Collection

You are allowed to collect the
location...

You are allowed to collect the
location... IF the location is a
restaurant.

Restaurant Collector

App

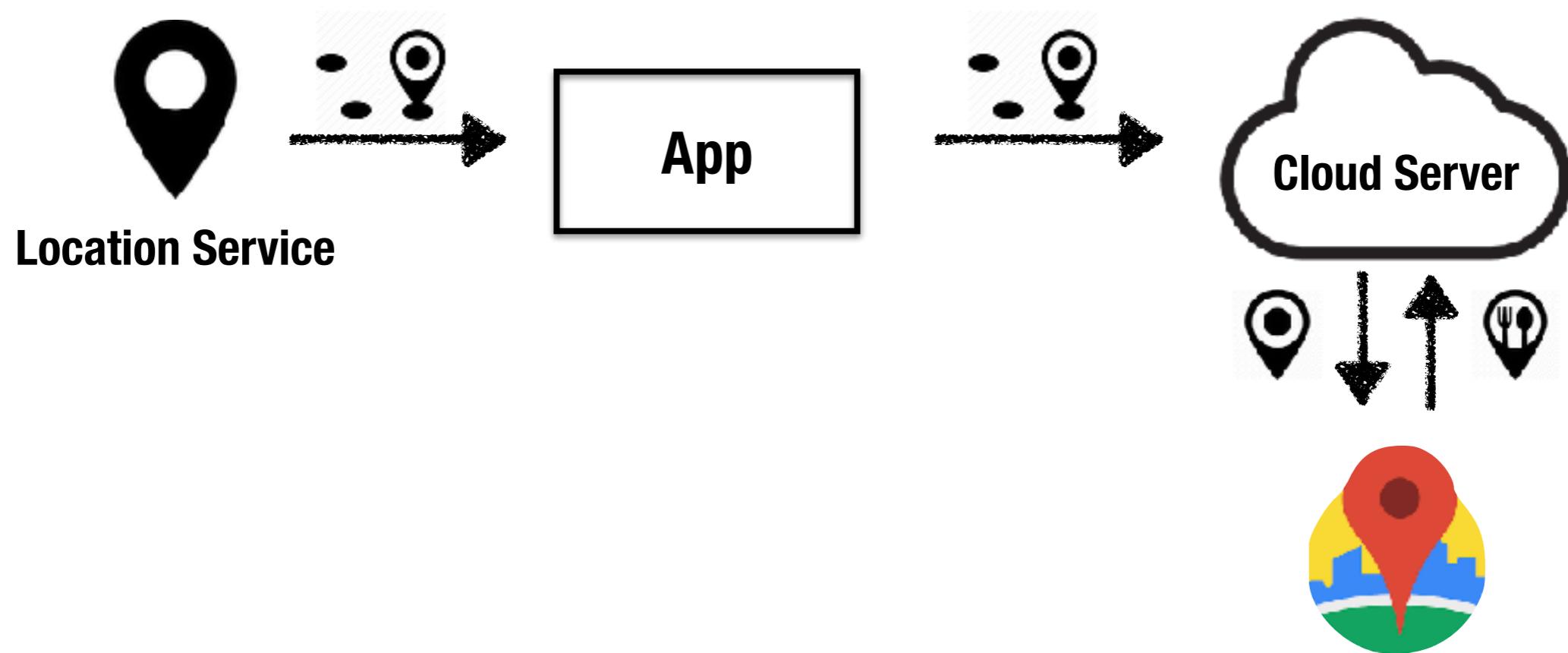
Restaurant Collector



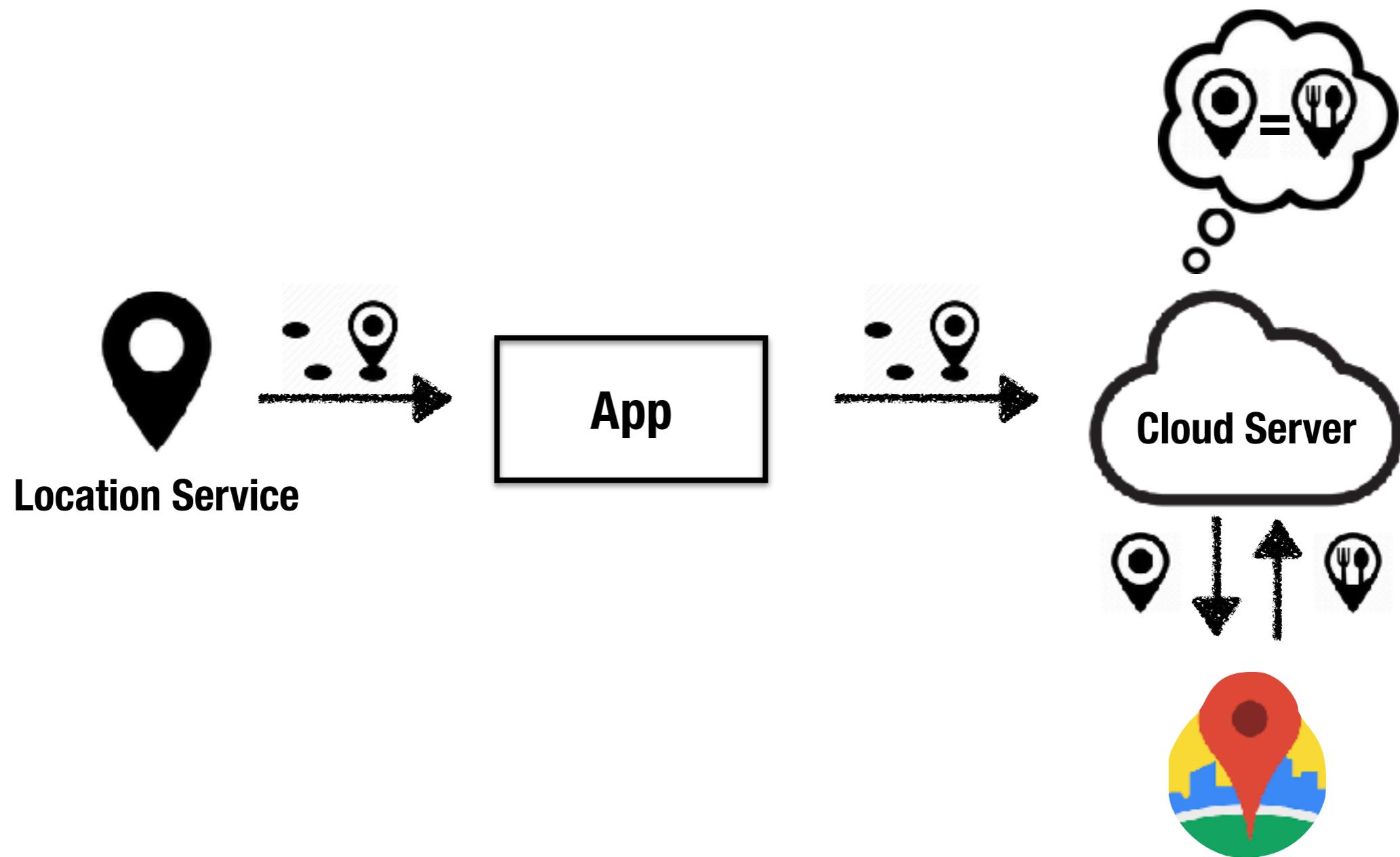
Restaurant Collector



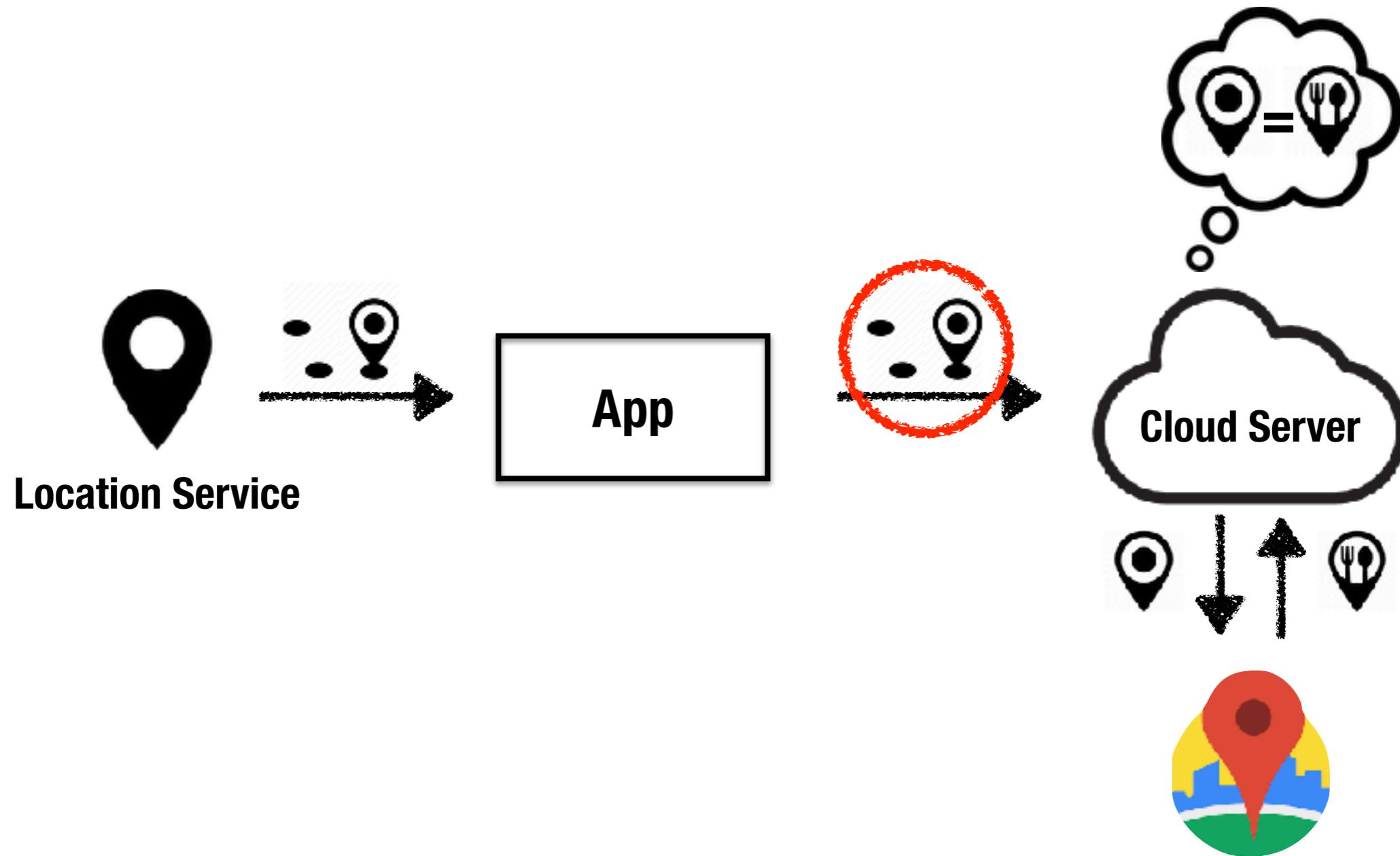
Restaurant Collector



Restaurant Collector



Restaurant Collector



Immutable Blobs

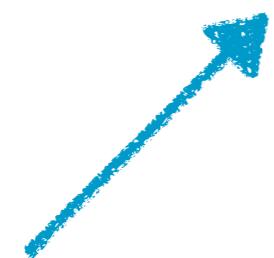
<JSON Data, Path, Signature>

Immutable Blobs

<JSON Data, Path, Signature>

```
"Location"
{
  "lat": 40.7155809802915,
  "lng": -73.9599399197085,
  "time": "2012-04-23T18:25:43.511Z"
}
```

```
"googleapis:place"
{
  "results": [
    { "name": "Subway",
      "types": ["restaurant"],
      ...
    }
  ...
}
}
```



Immutable Blobs

<JSON Data, Path, Signature>

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googleapis:place:
results:types

Immutable Blobs

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    }
    ...
  ]
}
```



googleapis:place:
results:types

Restaurant Collector

Collector



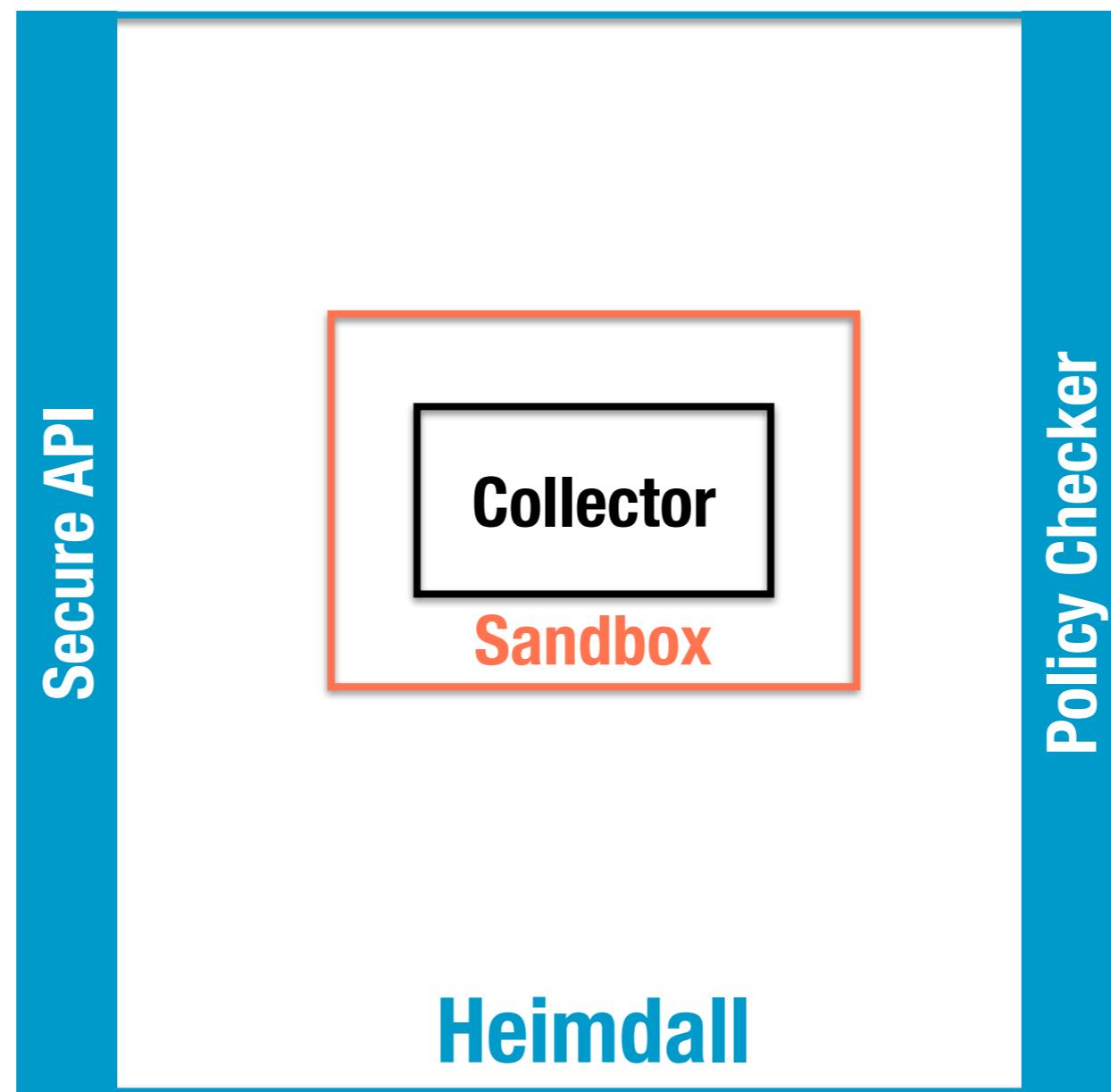
Immutable Blob: <JSON Data, Path, Signature>

Restaurant Collector



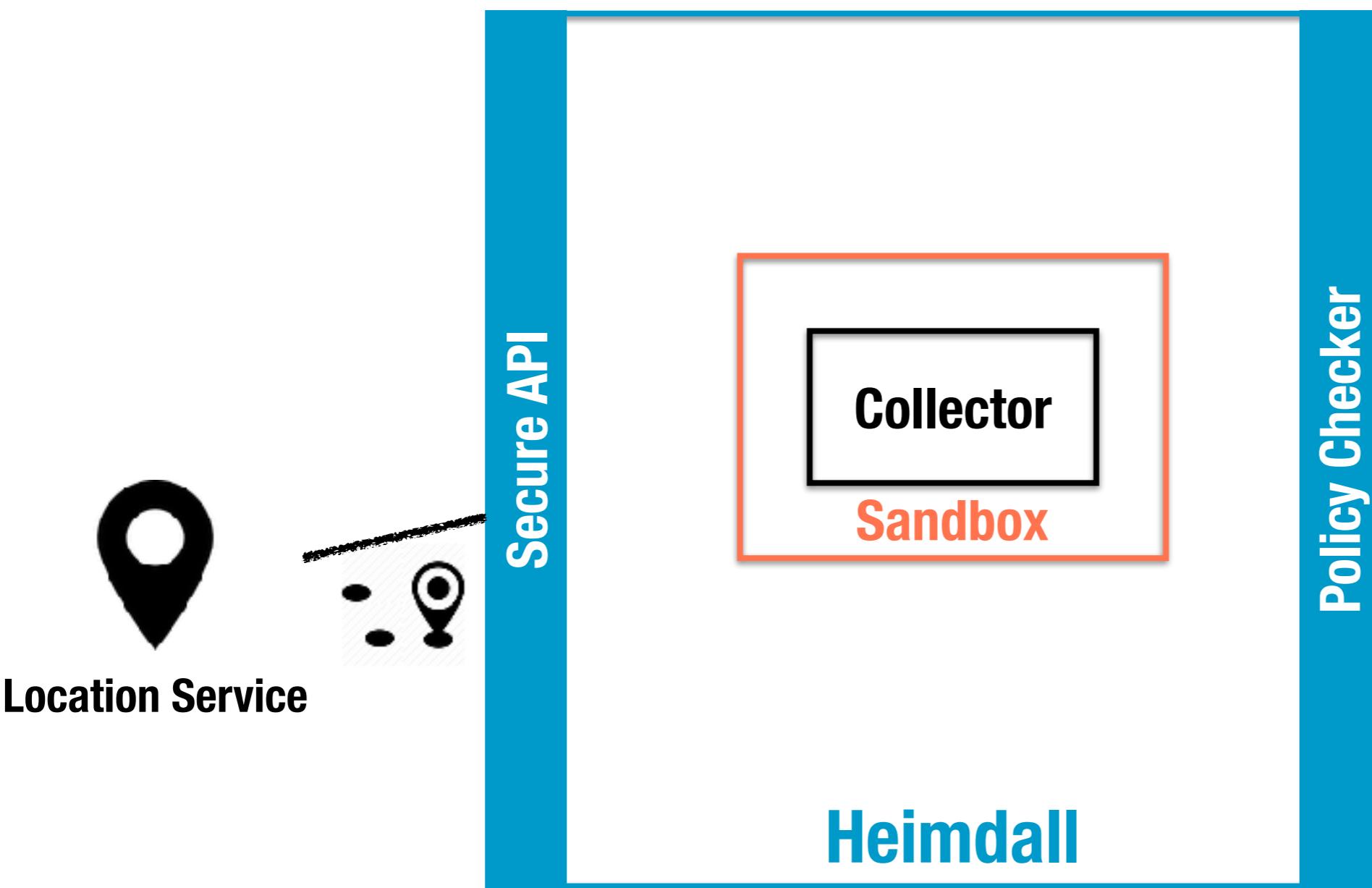
○ Immutable Blob: <JSON Data, Path, Signature>
13

Restaurant Collector



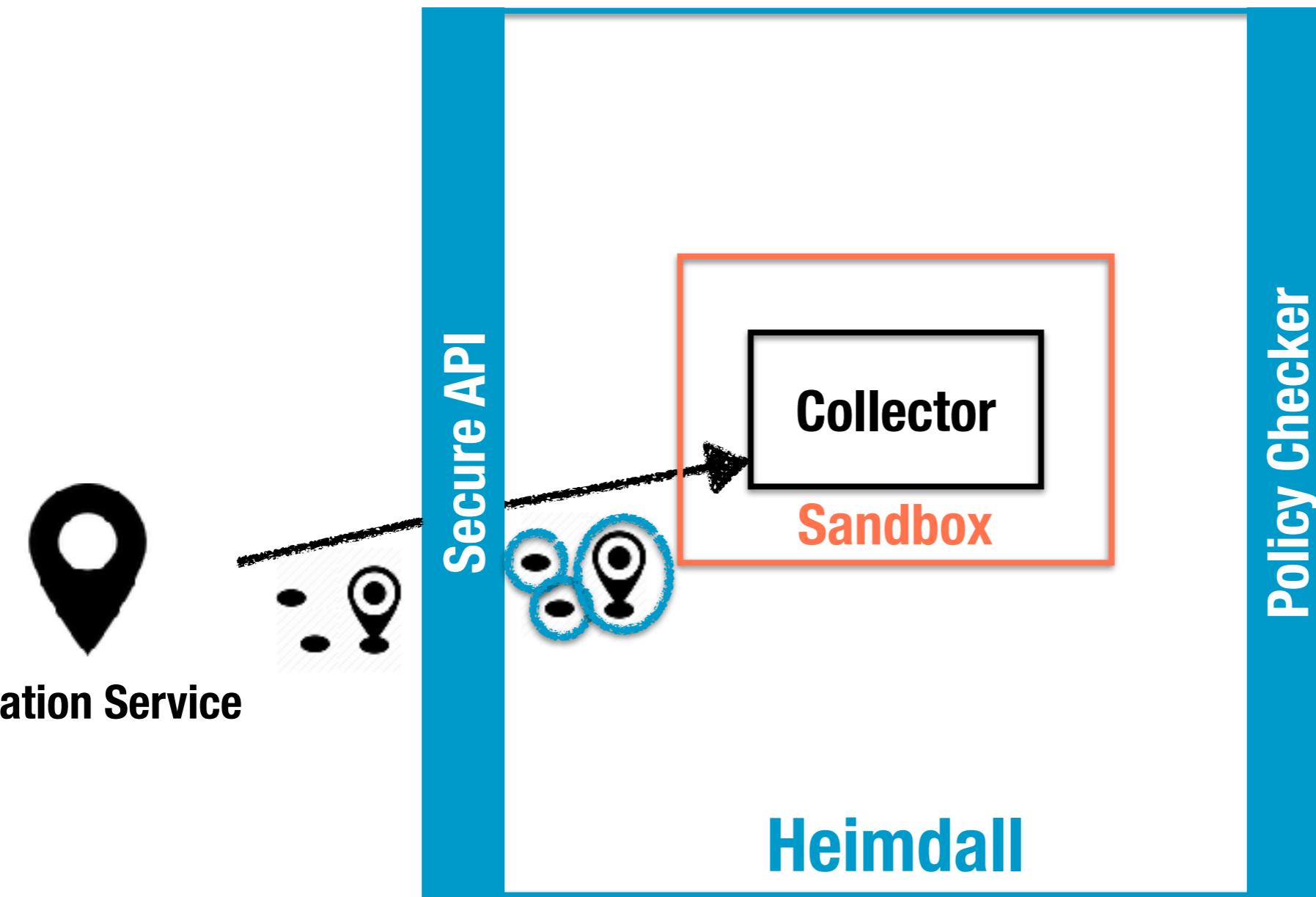
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Restaurant Collector



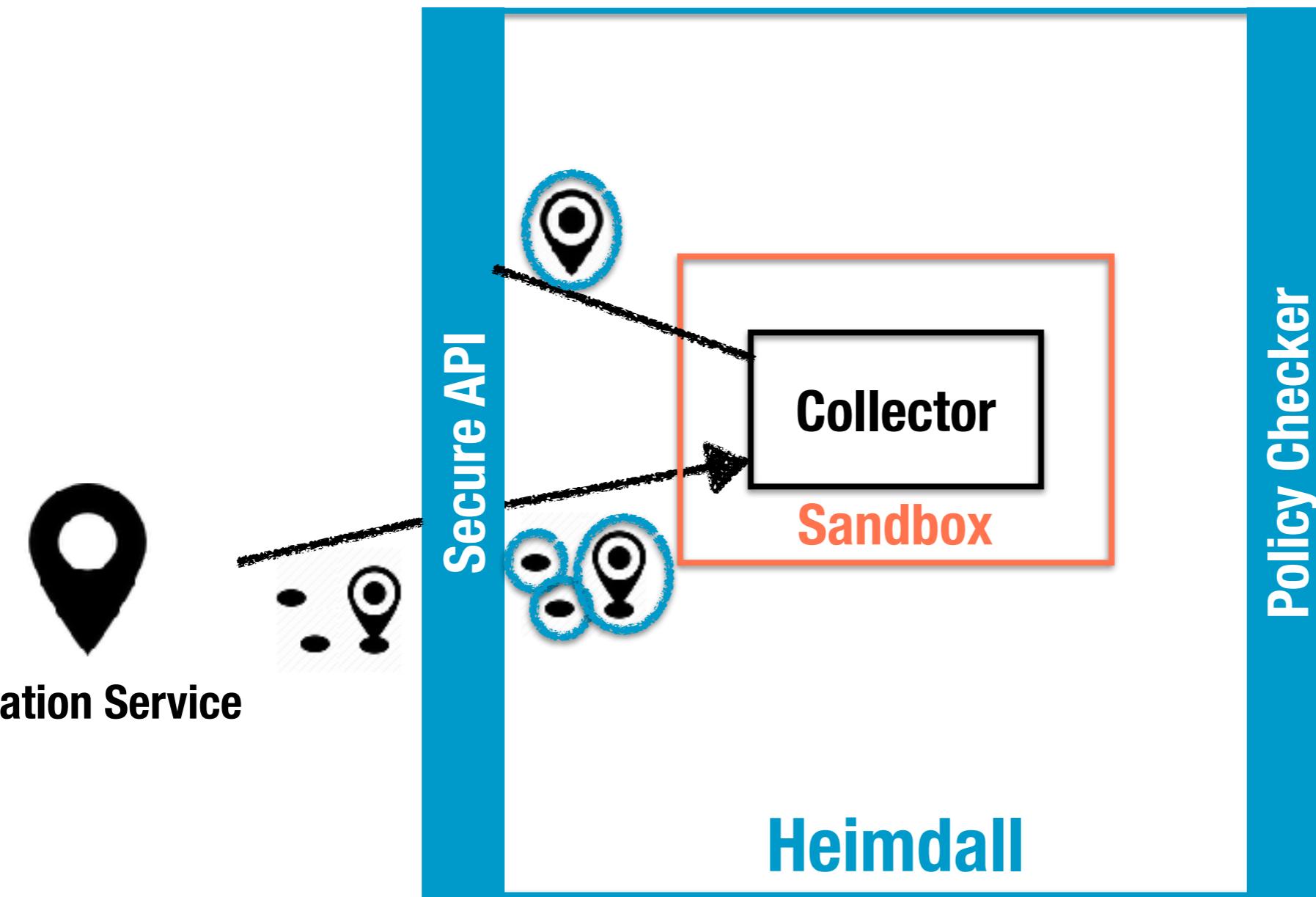
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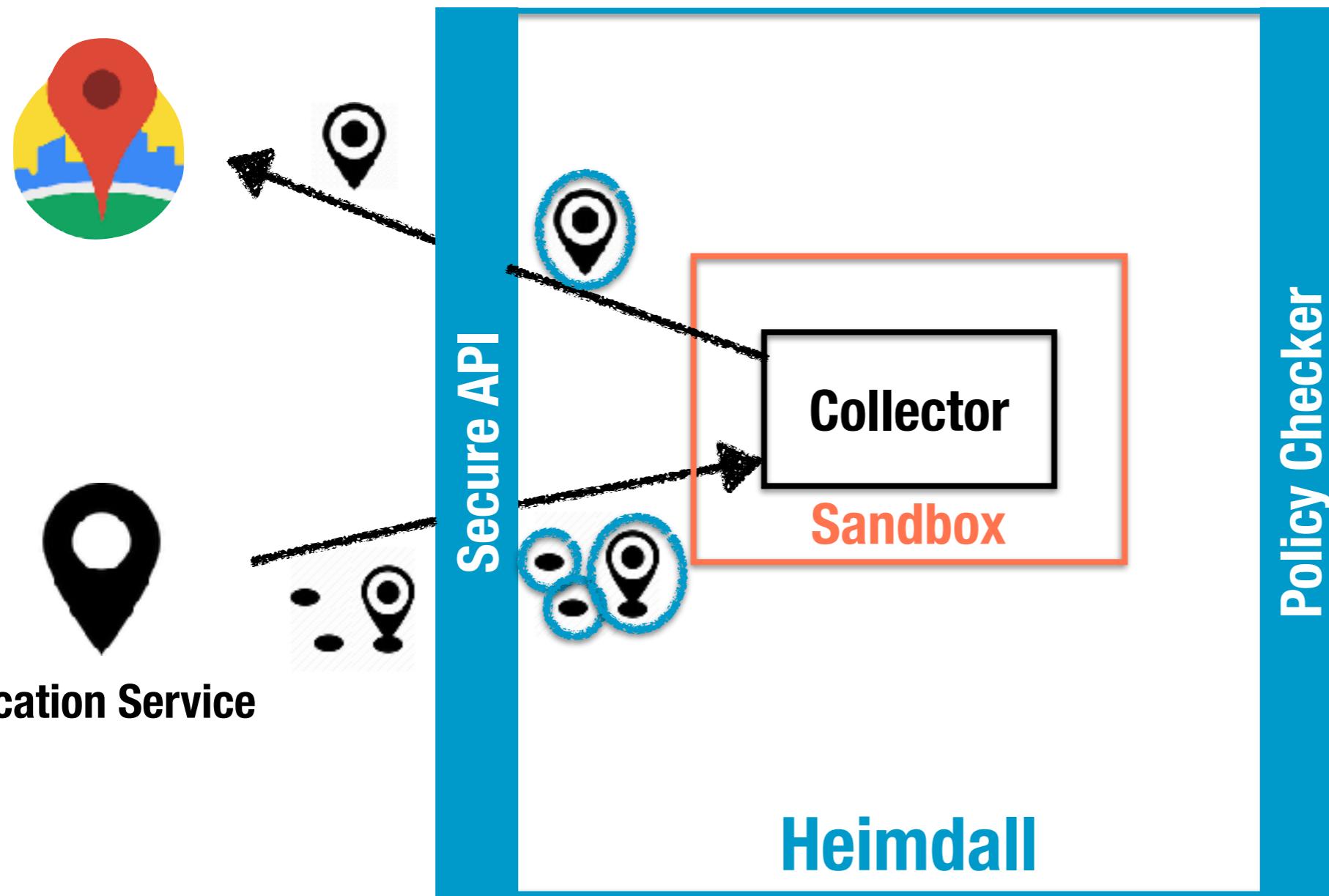
Immutable Blob: <JSON Data, Path, Signature>

Restaurant Collector



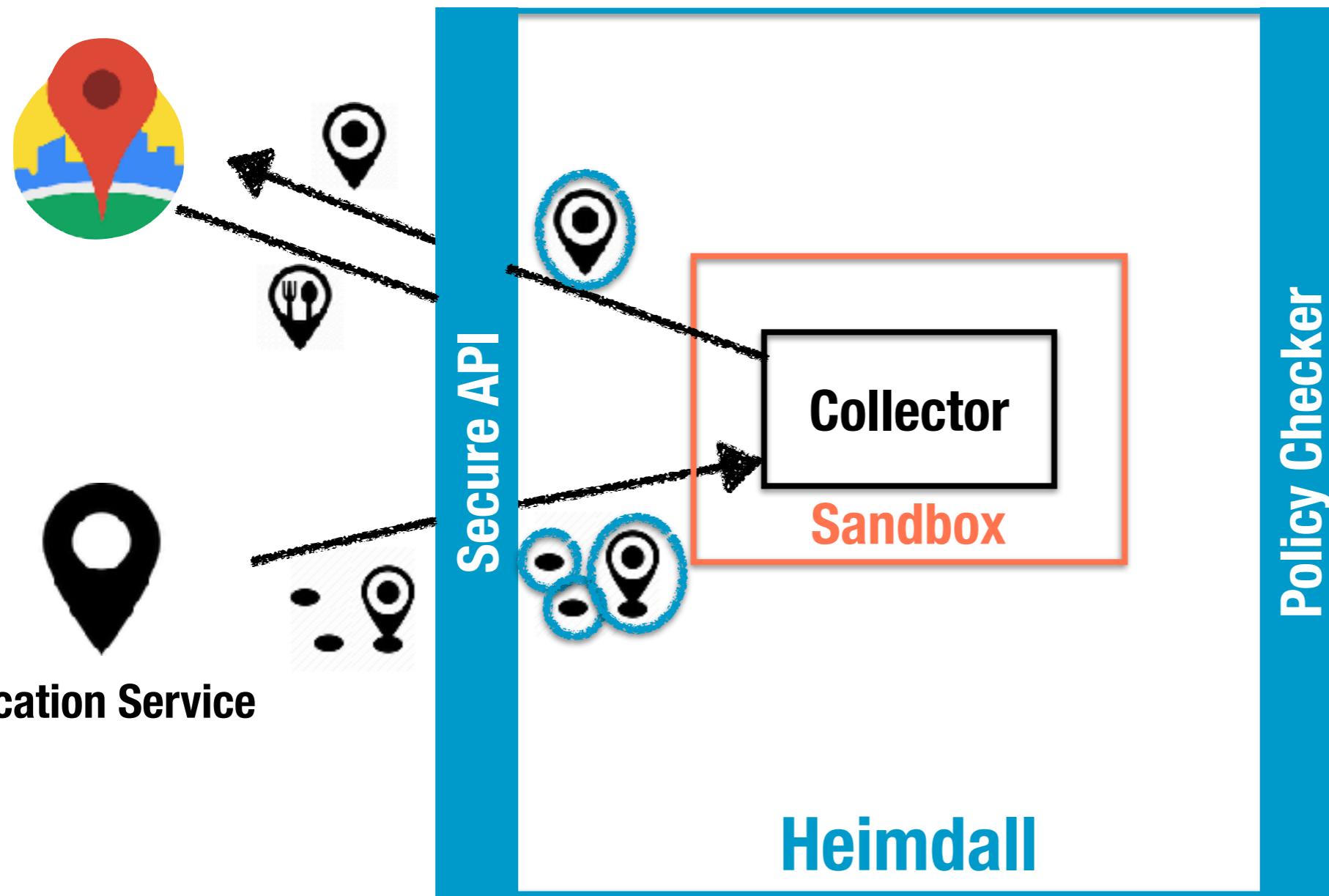
Immutable Blob: <JSON Data, Path, Signature>

Restaurant Collector



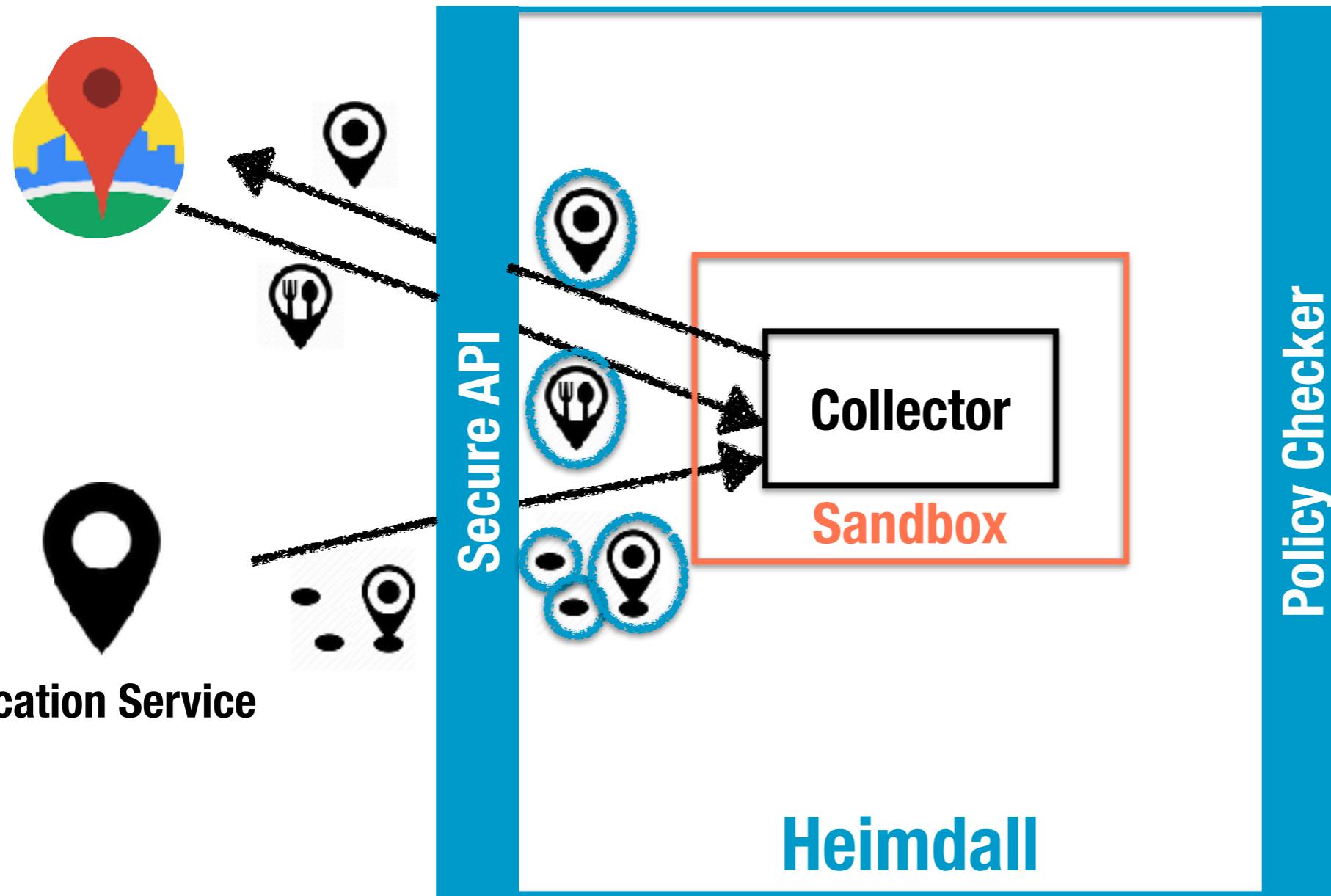
Immutable Blob: <JSON Data, Path, Signature>

Restaurant Collector

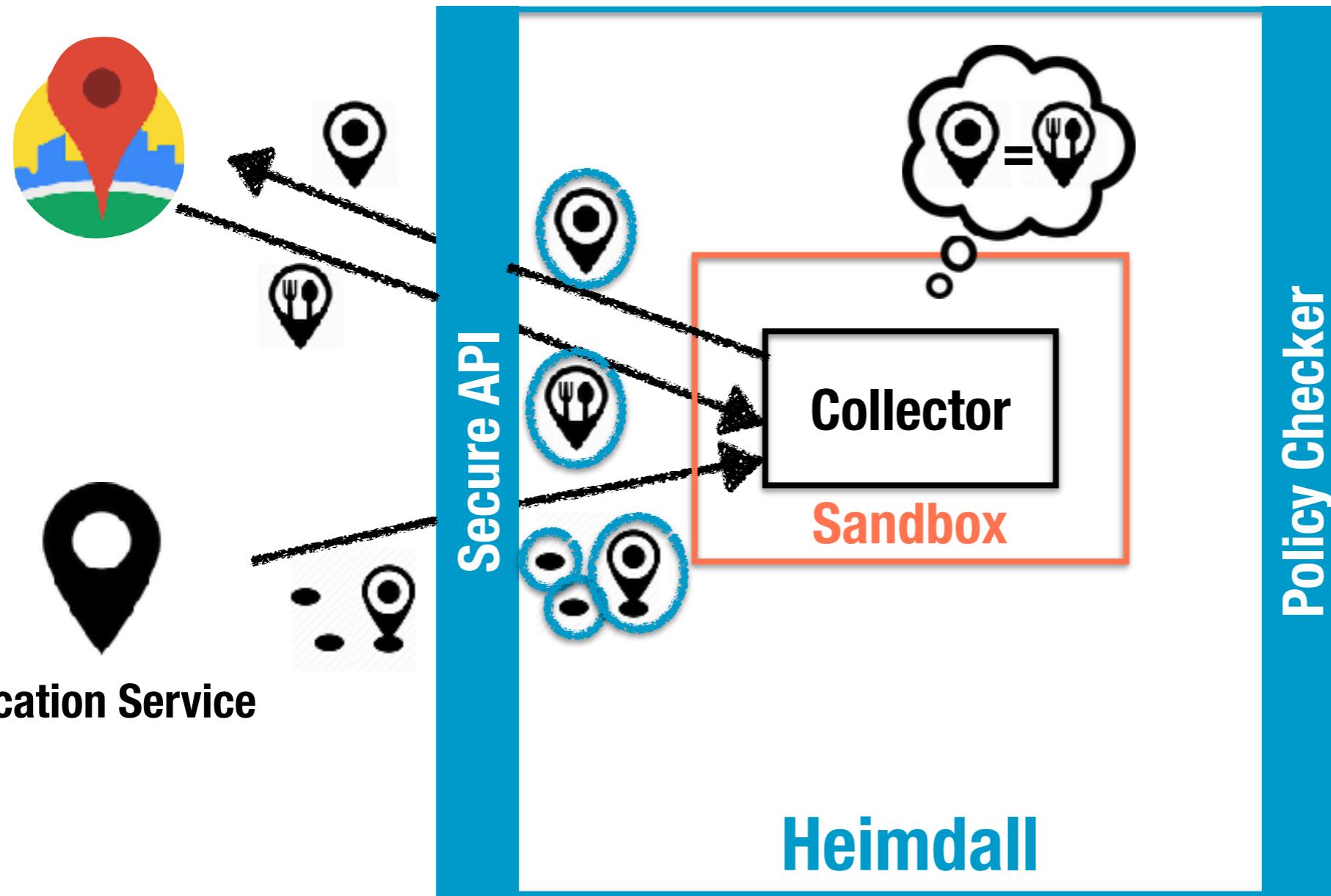


Immutable Blob: <JSON Data, Path, Signature>

Restaurant Collector

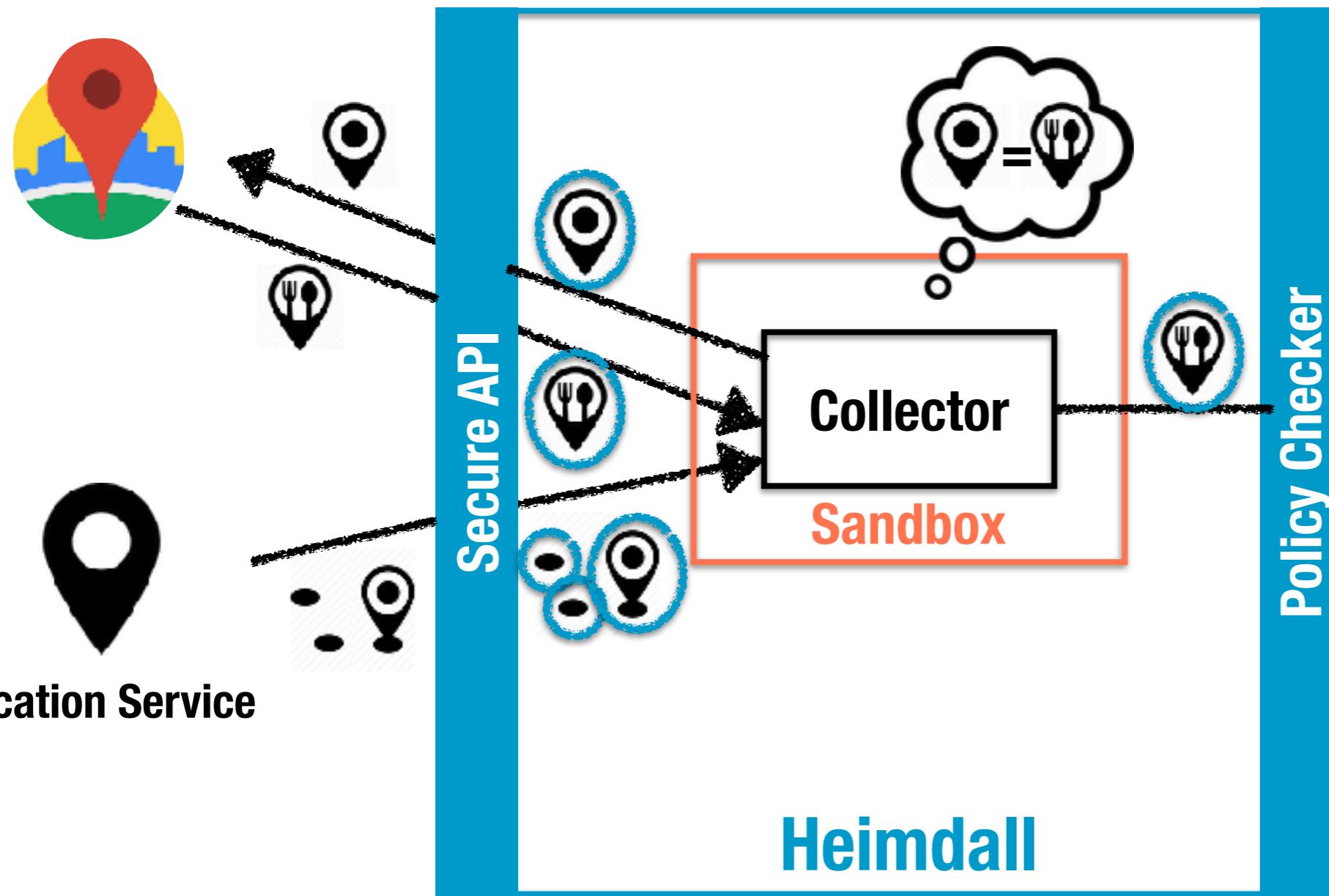


Restaurant Collector



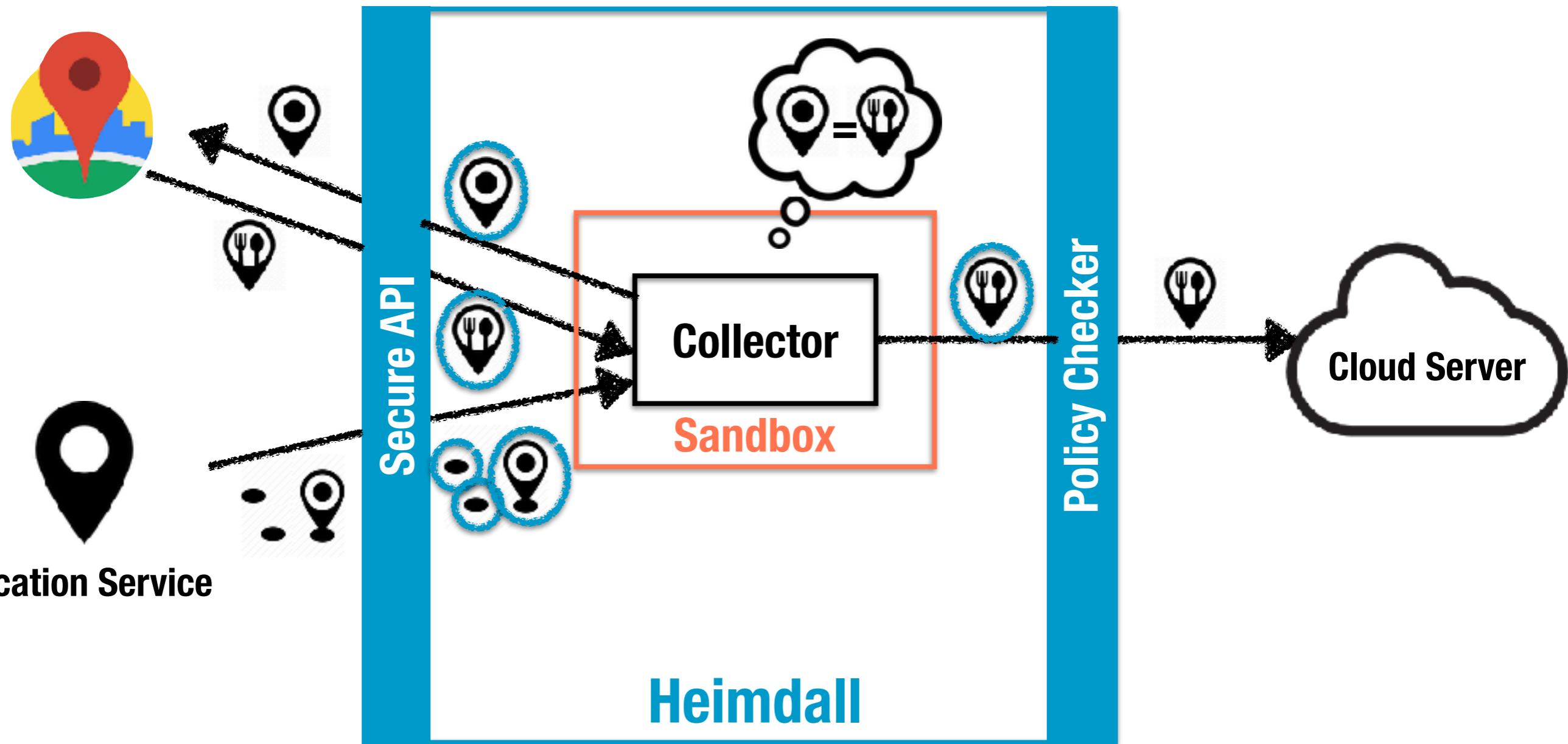
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Restaurant Collector



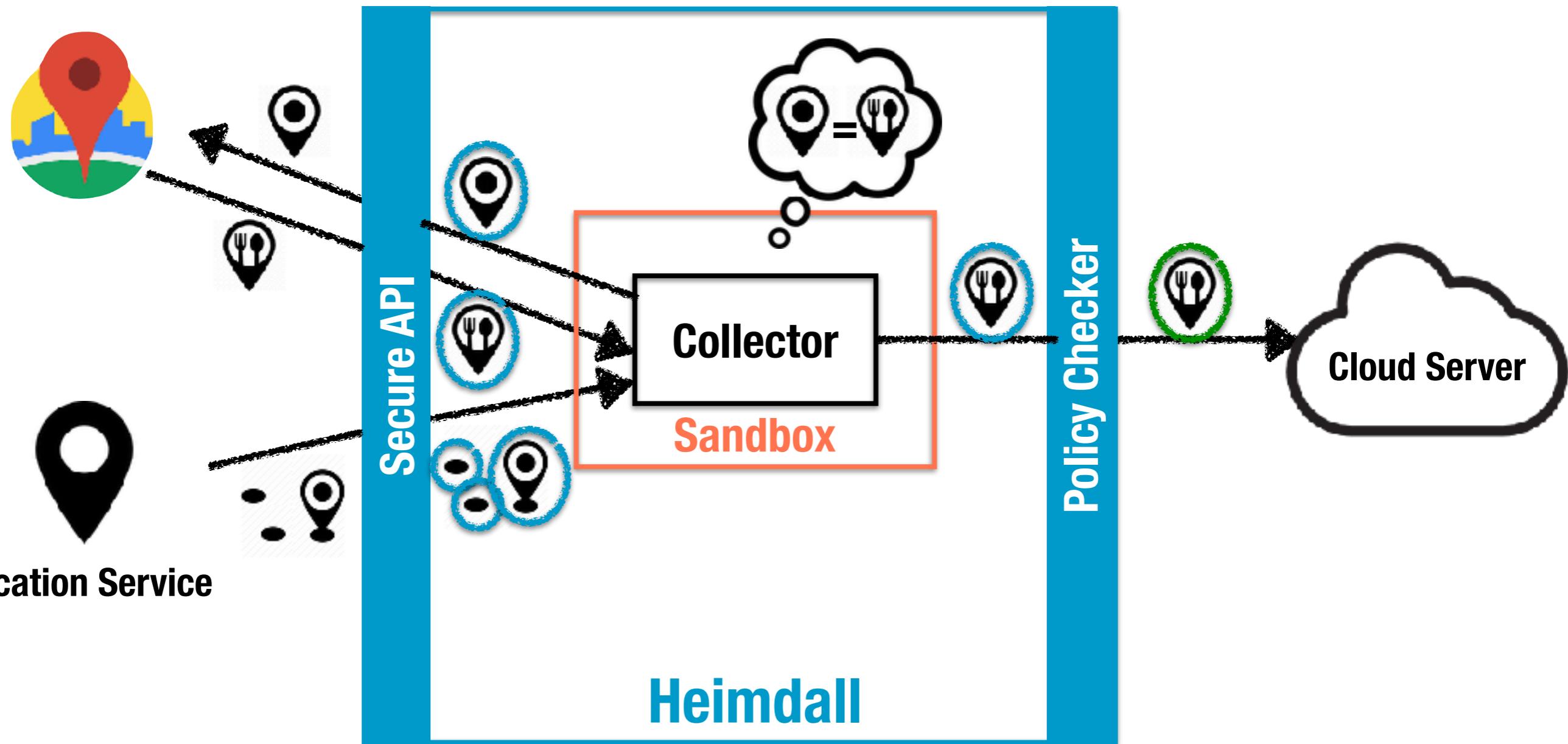
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Restaurant Collector



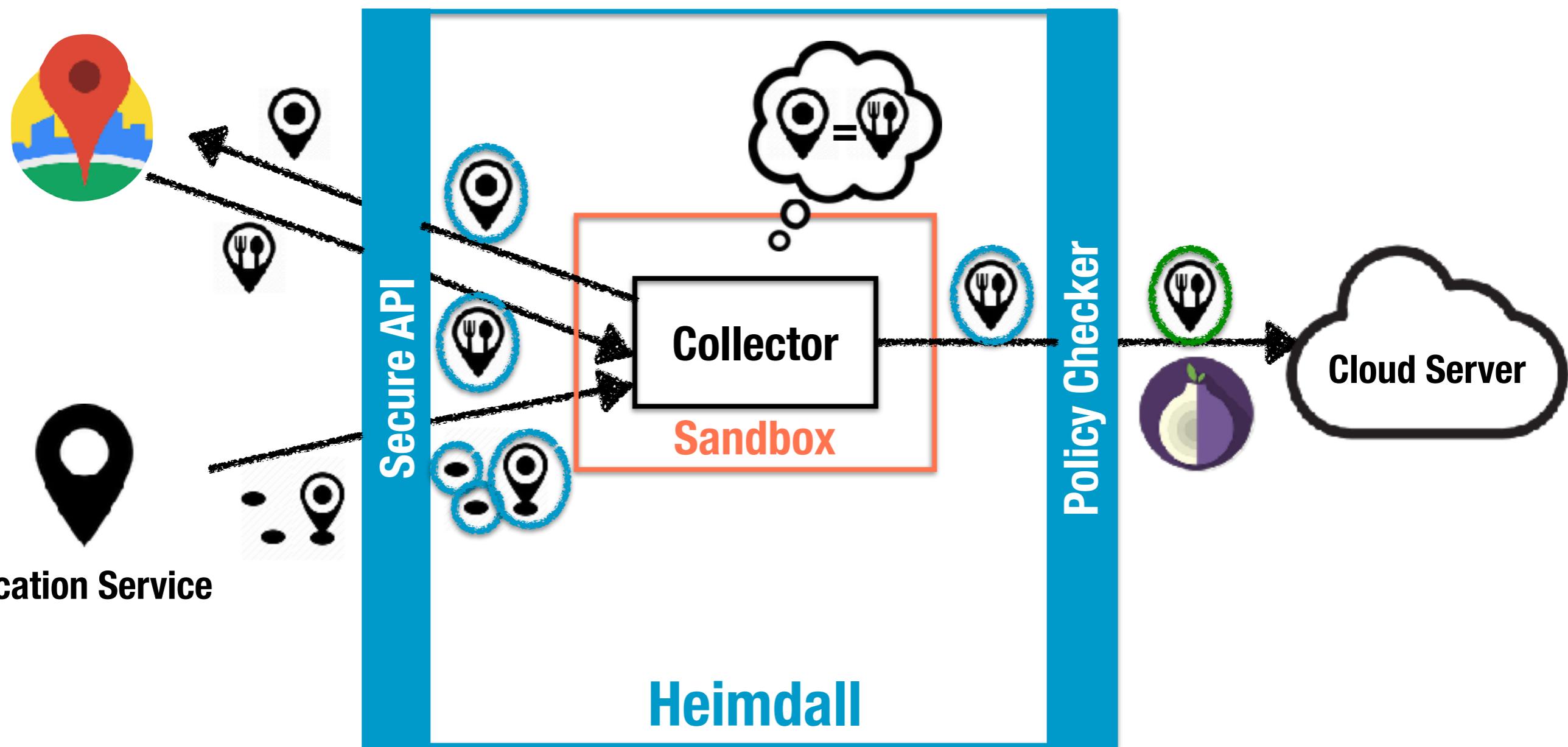
Immutable Blob: <JSON Data, Path, Signature>

Restaurant Collector



Immutable Blob: <JSON Data, Path, Signature>

Restaurant Collector



Immutable Blob: <JSON Data, Path, Signature>

Restaurant Collector

#Sources:

```
FINE_LOCATION  
googleapis:place
```

#Collects:

```
@anonymized  
if(googleapis:place:results:types=="restaurant"):  
    submit(googleapis:place:results:name, "Link")
```

Restaurant Collector

#Sources:

```
FINE_LOCATION  
googleapis:place
```

#Collects:

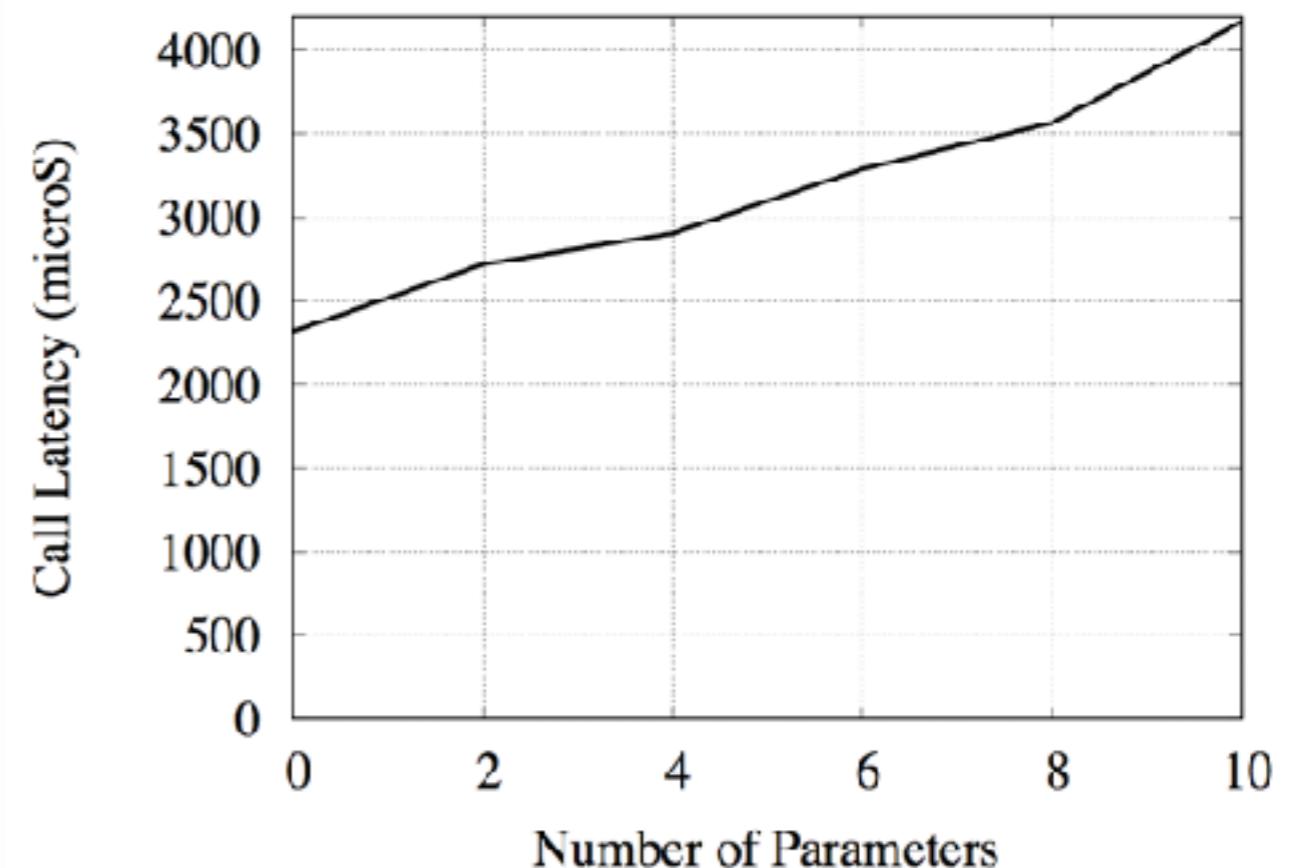
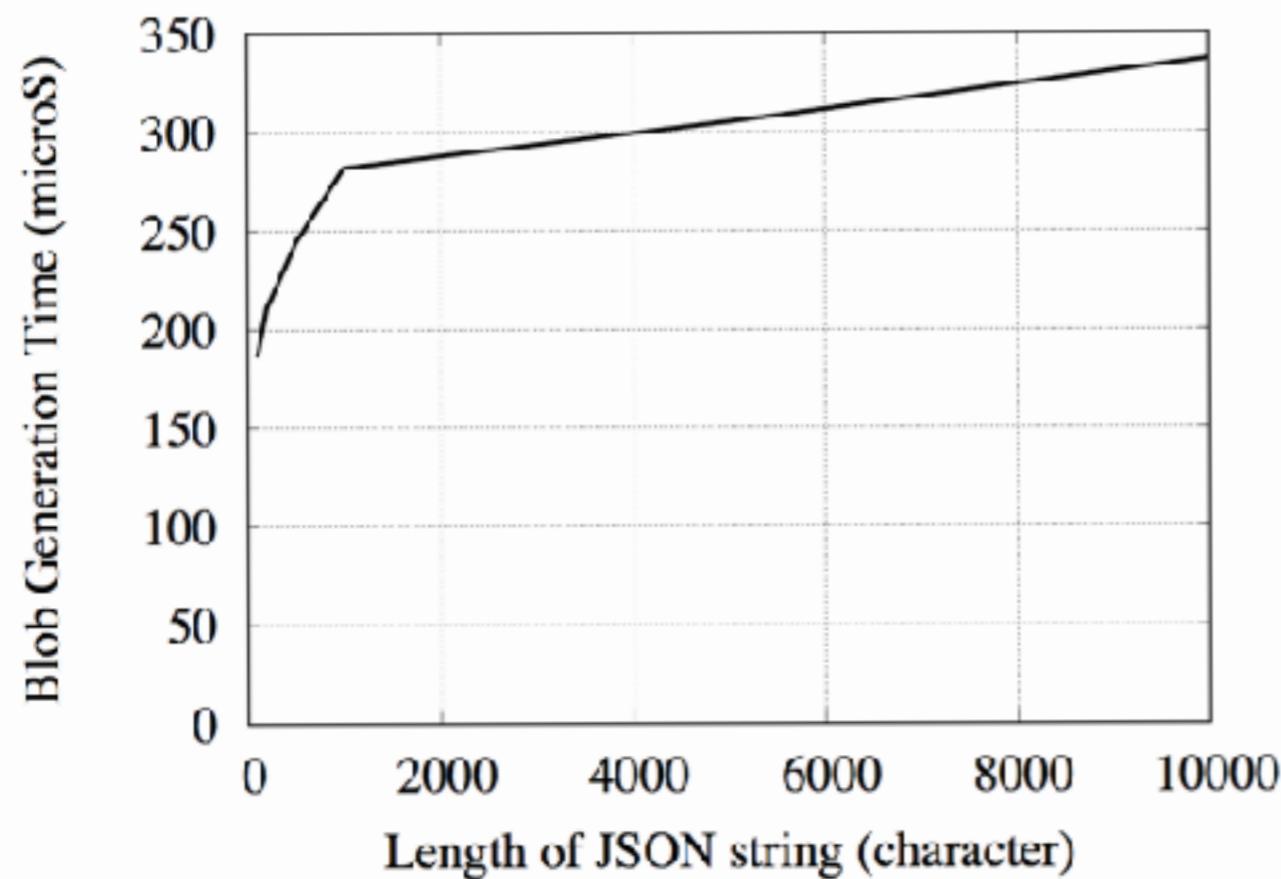
```
@anonymized  
if(googleapis:place:results:types=="restaurant"):  
    submit(googleapis:place:results:name, "Link")
```

Supports relational constraints

Evaluation

- How is the performance of Heimdall?
- Can you develop useful collectors using Heimdall?
- Does Heimdall decrease user concerns?

MicroBenchmarks



Likert Scale

1. **Not Concerned** - Select this for actions which pose little to no risk to you or the people living with you.
2. **Mildly Concerned** - Select this for actions which pose a low risk to you or the people living with you, but are useful when used as intended.
3. **Concerned** - Select this for actions which pose a medium risk to you or the people living with you, but are useful when used as intended.
4. **Very Concerned** - Select this for actions which pose a high risk to you or the people living with you, but are useful when used as intended.
5. **Would Not Allow** - Select this for actions which pose a high risk to you or the people living with you and are better left disabled.

Results

Results

- Location
 - Reporting location all the time
 - Reporting location when using the app
 - Reporting name of restaurants

Results

- Location
 - Reporting location all the time
 - Reporting location when using the app
 - Reporting name of restaurants

Results

- Location
 - Reporting location all the time
 - Reporting location when using the app
 - Reporting name of restaurants
- Purchase History
 - Reporting purchases all the time
 - Reporting food purchases

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Results

- Location
 - Reporting location all the time
 - Reporting location when using the app
 - Reporting name of restaurants
- Purchase History
 - Reporting purchases all the time
 - Reporting food purchases
- Browser History
 - Reporting all your browsing history
 - Reporting restaurant websites you browsed

Heimdall: A Privacy-Respecting Implicit Preference Collection Framework

- We empirically show that recommendation systems suffer from sparsity of data.
- Heimdall allows users to control what type of data they are sharing with recommendation systems.
 - This allows recommendation systems to collect implicit signals while respecting user privacy.
- We implemented 3 data collectors using Heimdall and evaluated Heimdall performance and user response to it.