The Path Transparency Observatory

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measurement and architecture for a middleboxed internet

measurement | architecture | experimentation

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Scaling Path Transparency Measurement

- with PATHspider, we've seen...
  - measurements from a single machine
  - in a single run
- How to compare measurements...
  - from multiple vantage points
  - across longer time scales?

- Answer: centralize analysis in an ***observatory***.

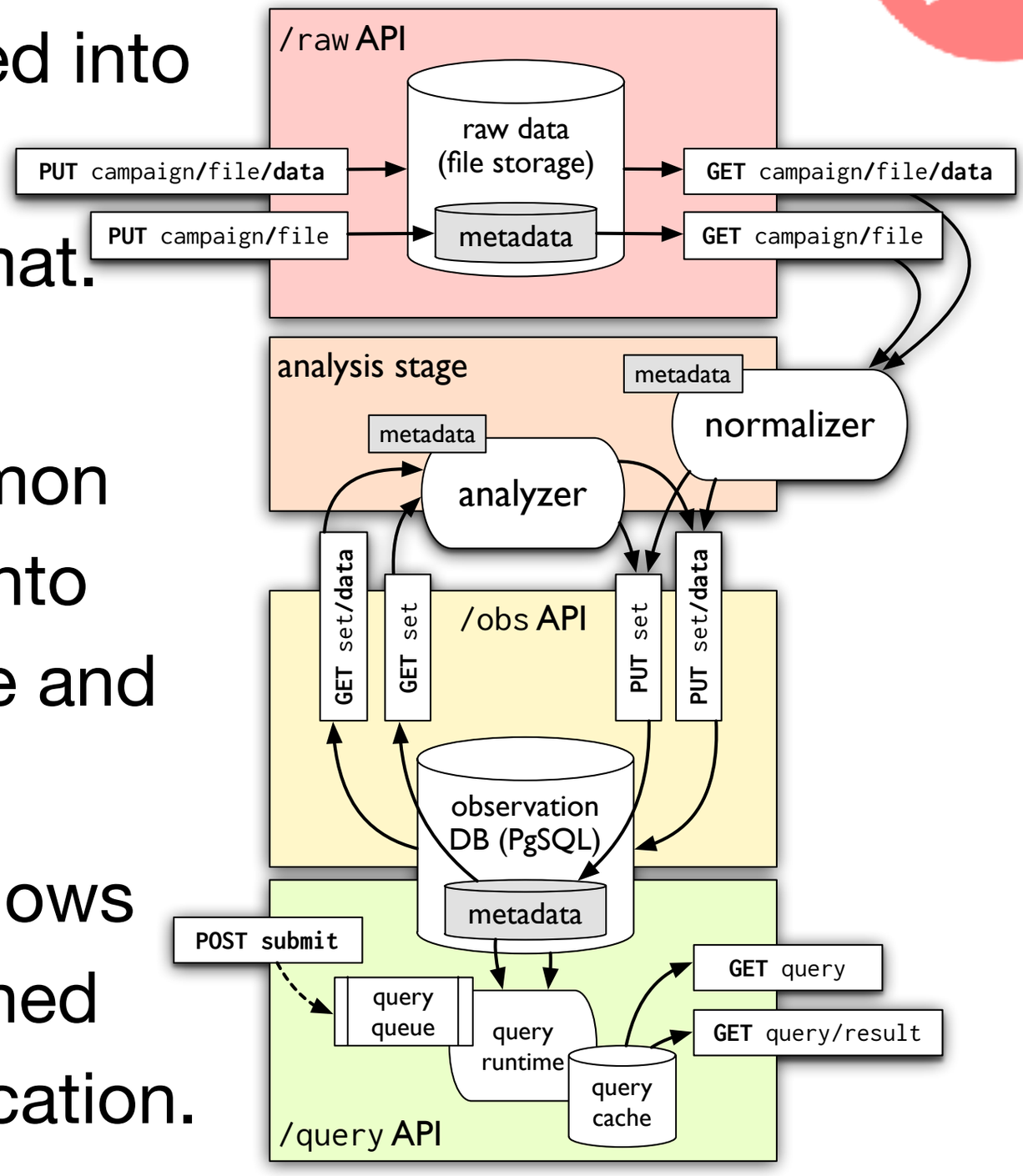
Observatory Design Goals

Measurement data observatories can support better science through the following design goals:

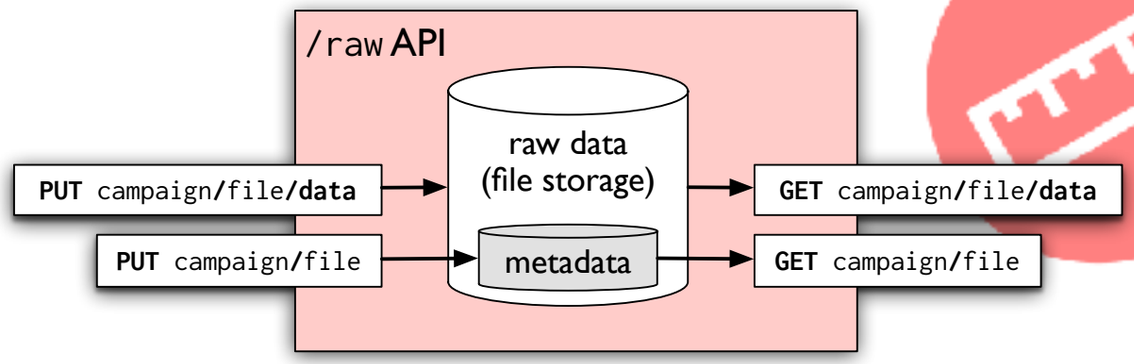
- Comparability: allow the results from diverse tools to be expressed in the same vocabulary so they can be compared.
- Repeatability: keep enough metadata around so that future users of the data know how to repeat the experiment.
- Protection: reduce information in raw data to only that needed for a particular analytical task.

PTO design

- Raw data store organized into ***campaigns*** containing ***raw files*** in original format.
- Analysis stage derives ***observations*** in a common data model, organized into sets sharing provenance and other metadata
- Flexible query engine allows ***query*** results to be cached and annotated for publication.



Raw Data and Metadata



- Every campaign and datafile is associated with metadata
  - Metadata must be created before data is uploaded
  - Metadata mutable, data is not
  - Raw files inherit metadata
- ***System metadata*** required for every file:
  - `_time_start, _time_end:` time interval covered by measurements
  - `_owner`: who owns the raw data (and should be contacted for questions about it), as email address or URI.
- ***User metadata*** is freeform

Upload: creating a campaign

- First, set up your environment: you'll need your API key and campaign name:

```
$ export TOKEN="your API key"
$ export CAMPAIGN="your campaign name"
```

- Then, create metadata for your campaign, as a JSON file with these keys:

```
{
    "_owner": "your email address",
    "_file_type": "pathspider-v2-ndjson-bz2"
}
```

Upload: creating a campaign

- ```
  $ curl -X PUT
         -H "Content-type: application/json"
         -H "Authorization: APIKEY $TOKEN"
         https://summer.pto.mami-project.eu/raw/$CAMPAIGN
         --data-binary @campaign-metadata.json
  ```

- Now we have a campaign. Next, let's upload some data into it...
  ```

Upload: Create and upload metadata

- Data files need at least a time range (`_time_start, _time_end`) in their metadata.
  - We can extract this from PATHspider output:

```
$ python3 extract_pathspider_metadata.py pathspider_files
```

- Now we can upload metadata for each file:

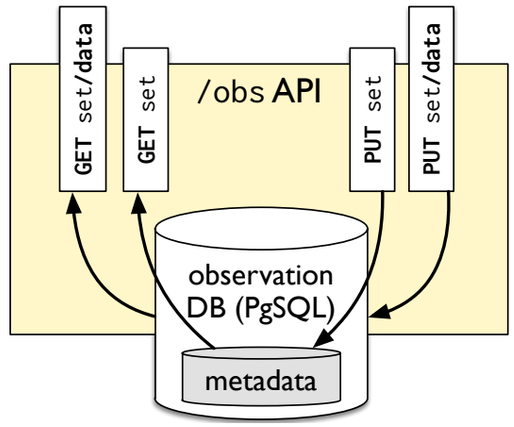
```
$ curl -X PUT
       -H "Content-type: application/json"
       -H "Authorization: APIKEY $TOKEN"
       https://summer.pto.mami-project.eu/raw/$CAMPAIGN/file
       --data-binary @file.meta.json
```

Upload: upload raw data

- And finally, data:

```
$ curl -X PUT
       -H "Content-type: application/bzip2"
       -H "Authorization: APIKEY $TOKEN"
       https://summer.pto.mami-project.eu/raw/$CAMPAIGN/file
       --data-binary @file
```

Observation Data Model



- Raw data is important for provenance and repeatability, but before we can query our data, we need to normalize it into observations.

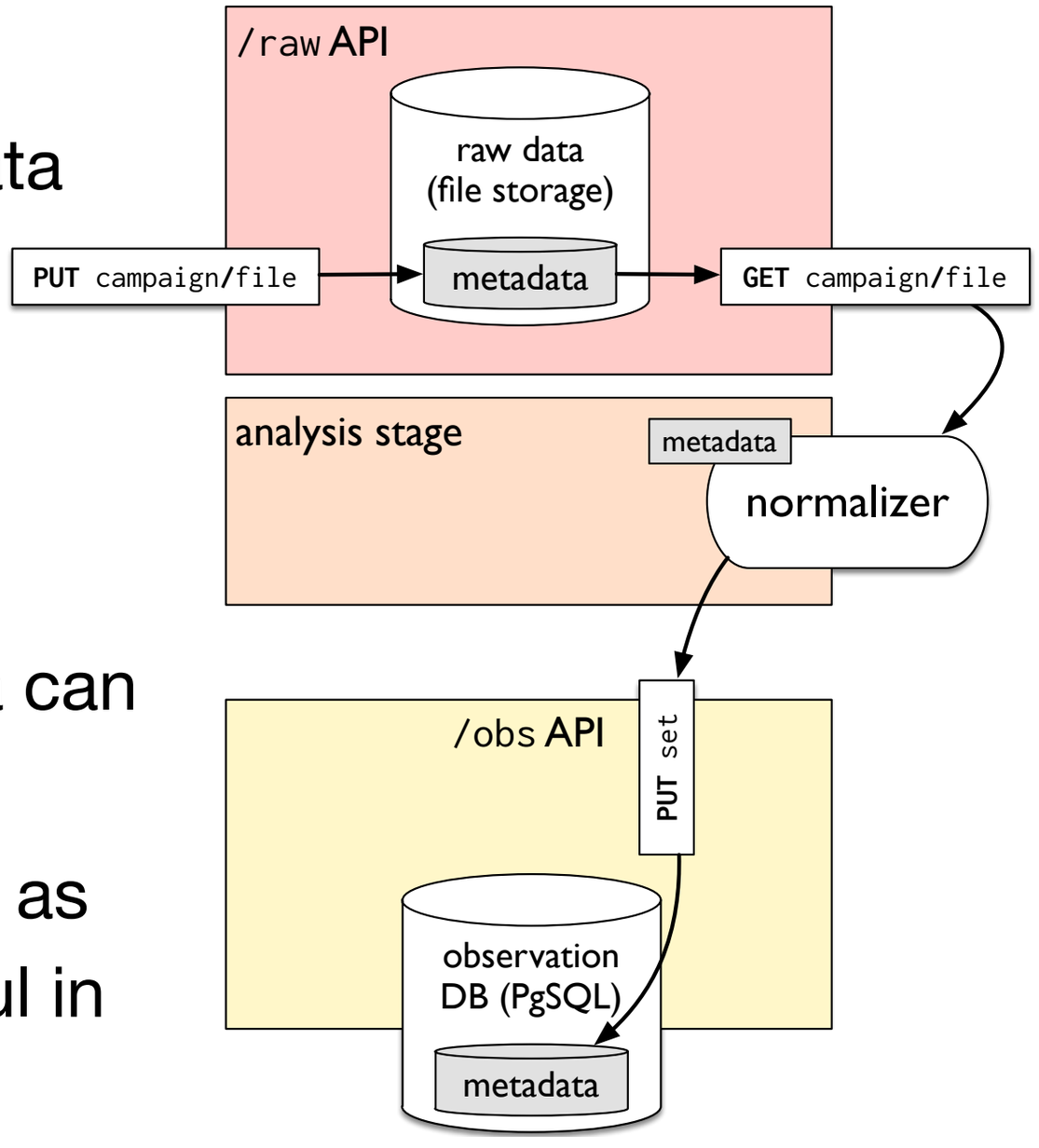
- An observation is an assertion that at a given **time**, a given **condition**, held on a given **path:**

```
["0","2014-08-28T22:41:02Z","2014-08-28T22:46:25Z",
  "* 82.192.86.197","ecn.multipoint.connectivity.works","3"]
```

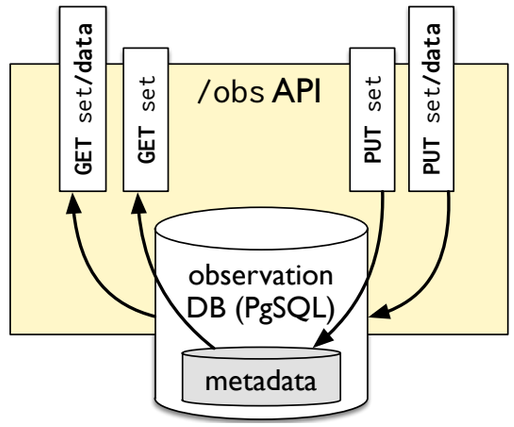
- Observations are organized into **sets**, which share metadata and provenance.

Metadata Flow

- PTO's design is **metadata-first:**
  - All additions consist of a metadata phase, then a data phase.
  - Normalizers and analyzers are controlled indirectly by raw and observation set metadata.
  - Data is immutable, but metadata can be updated.
- Arbitrary metadata: we don't know as well as the users what will be useful in the future.



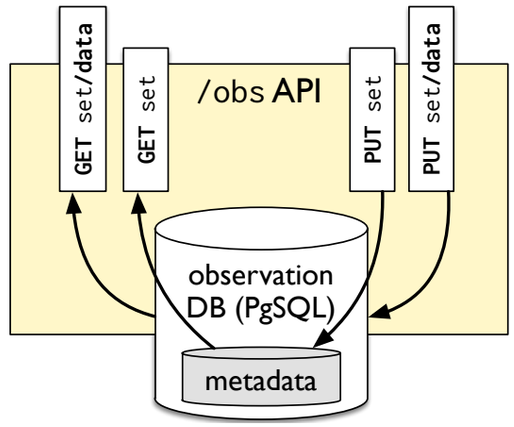
Conditions



- A condition is some **state** of an **aspect** of a **feature** observed on a network:
  - e.g. **ecn**.**connectivity**.**works** or **ecn**.**negotiation**.**reflected**

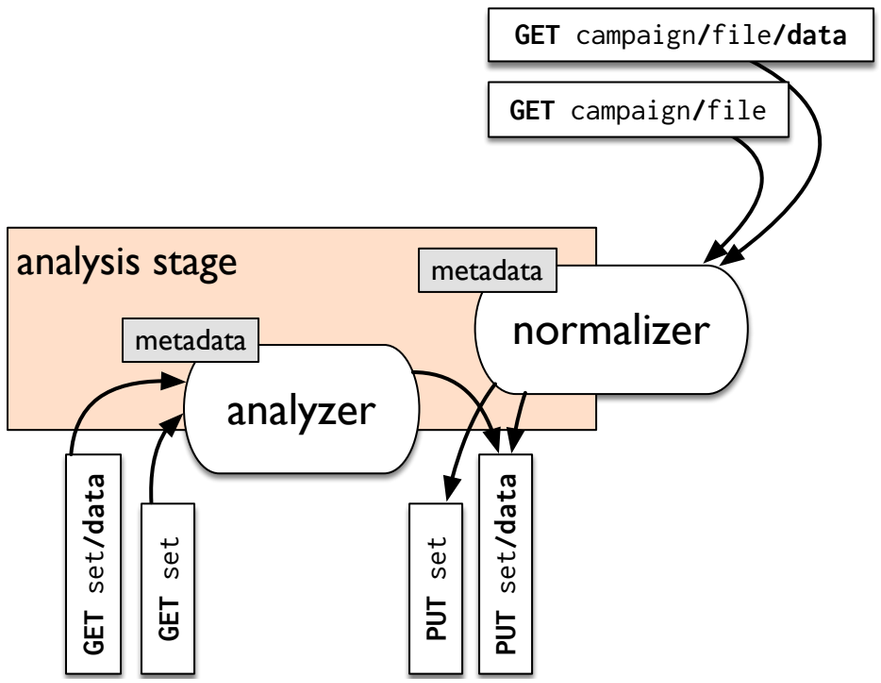
- Feature: what protocol or feature are we trying to use?
- Aspect: what question are we asking about the feature?
- State: what happens when we try to use it?
  - States mutually exclusive for a given aspect on a path at a given time.

Paths



- A path is a **sequence of path elements** (IP addresses, prefixes, AS numbers, pseudonyms, or wildcard) on which an observation was taken
- For active measurement: first path element is the **source** or device sending traffic, last path element is the **target** or device under test.
- e.g. `[digitalocean-ams3 * 104.24.127.228]` or `[128.10.18.52 * 209.200.170.230 204.106.55.245 * 159.45.6.20]`

Normalizers and Analyzers



- *Normalize* raw data and metadata into observations:
- **`ptonorm normalizer campaign file > obs.ndjson`**
  - takes data on stdin, metadata on fd 3
  - produces data + metadata on stdout
- **`ptoload obs.ndjson`**
  - loads resulting observation set

- *Analyze* observation sets into new observation sets:
- **`ptocat set₀ ... setₙ | analyzer > obs.ndjson`**

Step two: normalize raw data to observations

- Normalization and analysis take place on the PTO server itself.
- To normalize all the PATHspider files of a given type in a list of campaigns:

```
for c in `cat CAMPAIGNS`; do
    for f in `pushd -q $RAWSTORE/$c && ls *.bz2 && popd -q` do;
        ptonorm ecn_normalizer $c $f > $OBSCACHE/$c-$f.obs
        ptoload $OBSCACHE/$c-$f.obs
```

- (In a multi-owner environment, normalizers are provided by data owners, run by the observatory operator, and the resulting observation sets are vetted by the owner and operator before loading)

Step three: additional analysis

- Let's look for path dependency: different results for the same target from different sources. First, we need a list of sets to analyze:

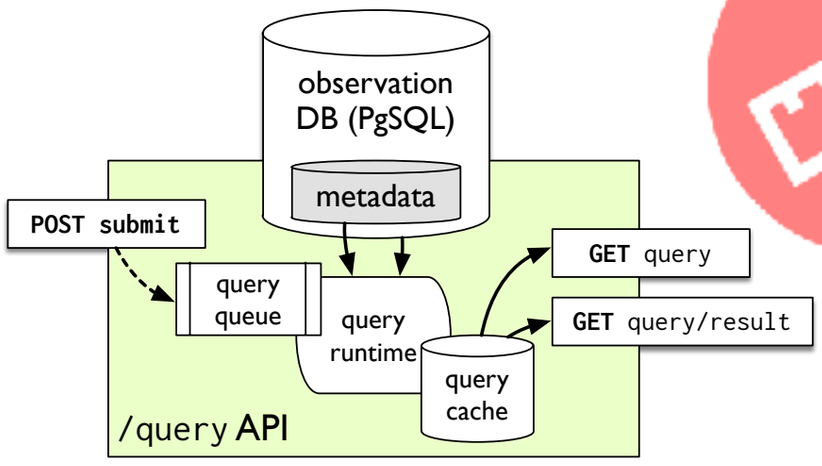
```
curl -H "Authorization: APIKEY $TOKEN"
      https://summer.pto.mami-project.eu/obs/by_metadata?\
      analyzer=https://raw.githubusercontent.com/\
      mami-project/pto3-ecn/master/ecn_normalizer/\
      ecn_normalizer.json | jq `.["sets"]`
```

Step three: additional analysis

- Now we can analyze all these sets, comparing results for the same target:

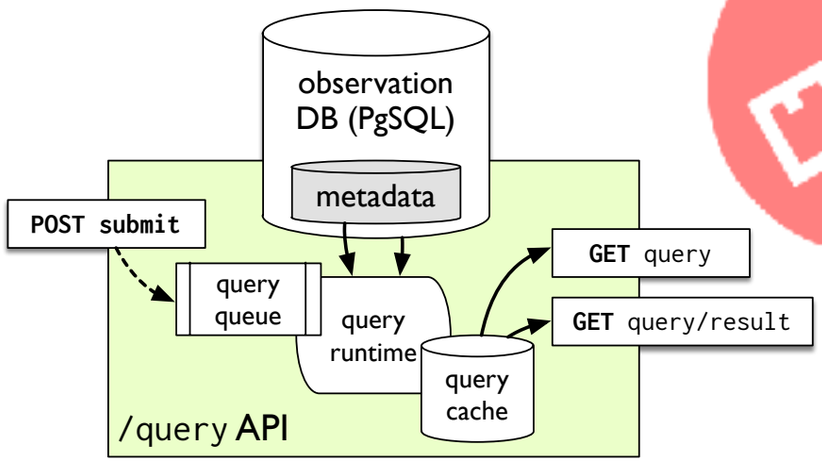
- `ptocat \`cat SETS\` | ecn_pathdep > pathdep.obs`
- `ptoload pathdep.obs`

Queries



- Queries select observations across observation sets based on predicates given in the query parameters.
- Queries are associated with metadata, and arbitrary metadata may be added to them.
- Query results are cached temporarily, and may be made permanent by adding an external reference to them.

Query Parameters



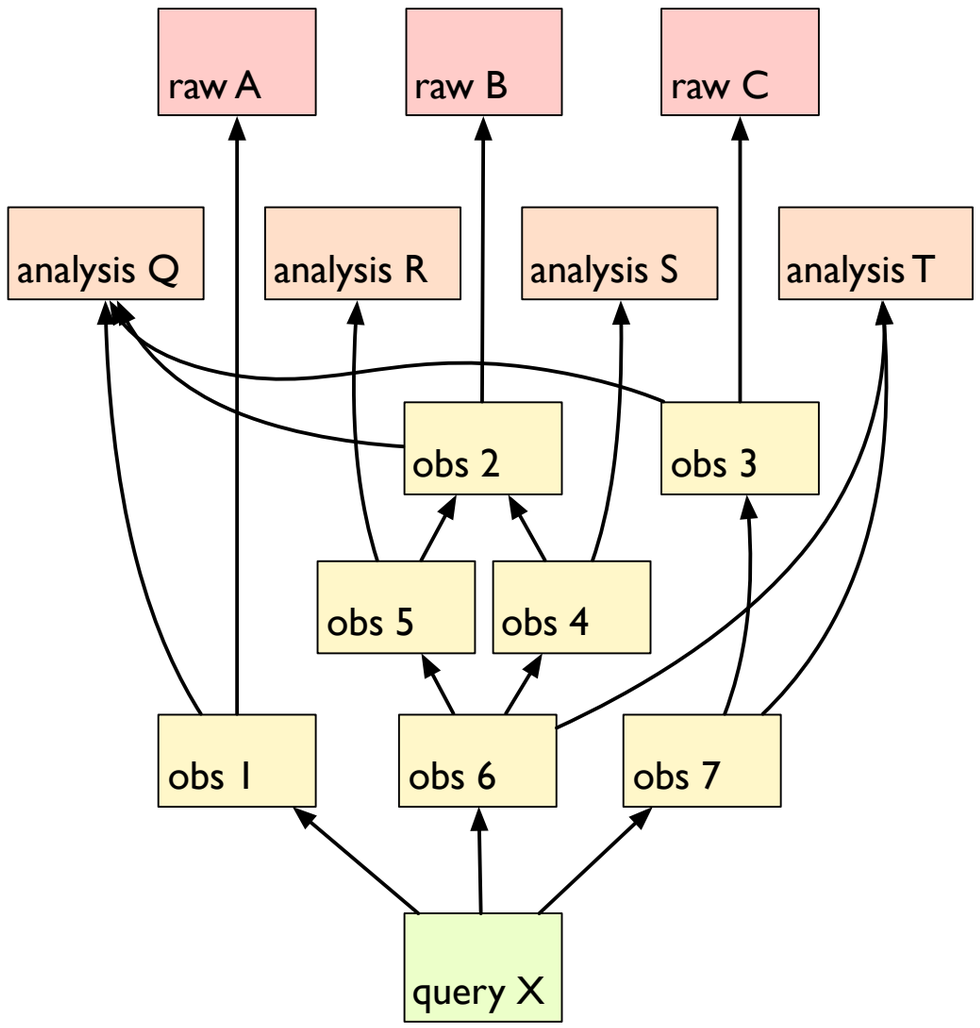
Parameter	Semantics	Meaning
`time_start`	temporal	Select observations starting at or after the given start time
`time_end`	temporal	Select observations ending at or before the given end time
`set`	select	Select observations with in the given set ID
`on_path`	select	Select observations with the given element in the path
`source`	select	Select observations with the given element at the start of the path
`target`	select	Select observations with the given element at the end of the path
`condition`	select	Select observations with the given condition, with wildcards
`group`	group	Group observations and return counts by group
`option`	options	Specify a query option

Step four: aggregate queries

- For working with queries, we use a Python client library in Jupyter notebooks:

```
$ cd summerschool/pto-notebook
$ jupyter notebook
```

Supporting Repeatability: Provenance



- Following `__sources`, `_sources`, and `_analyzer` links back from a query or observation set results in a **provenance tree.**
- This provenance tree is, in effect, a set of instructions for recreating a given observation set.

PTO: what we've seen

- a metadata-first observatory for supporting comparable and repeatable network measurements: this is a general design pattern you should consider in your future work.

- a data model and set of analysis and query tools for pulling path transparency measurements together into a single place, demonstrating the general design pattern.