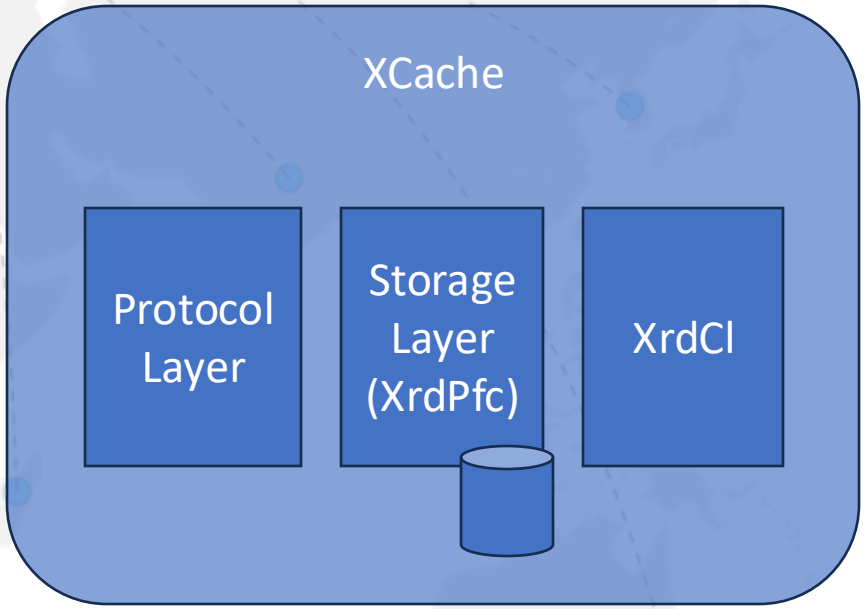
Making XCache Do What you Want

Writing XrdCl Plugins for fun and profit

XCache and XrdCl

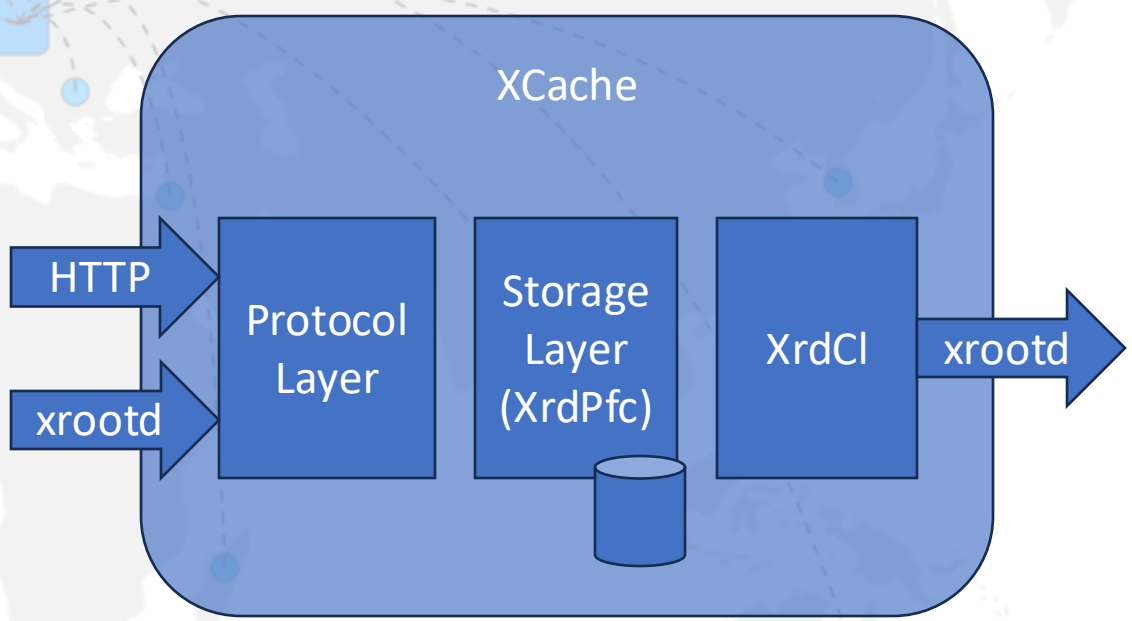
- XCache is the ‘caching proxy’ mode for XRootD.
- The cache itself is implemented as the “XrdPfc” (Proxy File Cache), a plugin for the XRootD storage layer.
  - Really is “just” a storage plugin like POSIX, S3, or HTTP backends.
  - Additional plugin layers expose the cache functionality.



A highly abstracted view of what’s inside an xrootd daemon when configured in XCache mode.

XCache and XrdCl

- When a request comes in, XrdPfc determines if the requested data is available locally.
  - If local, it's served from storage.
- On a cache miss, XrdPfc needs to download the missing data.
- How? Use the XrdCl client!
  - Great synergy: XCache uses the exact same client library underlying the venerable xrdcp.



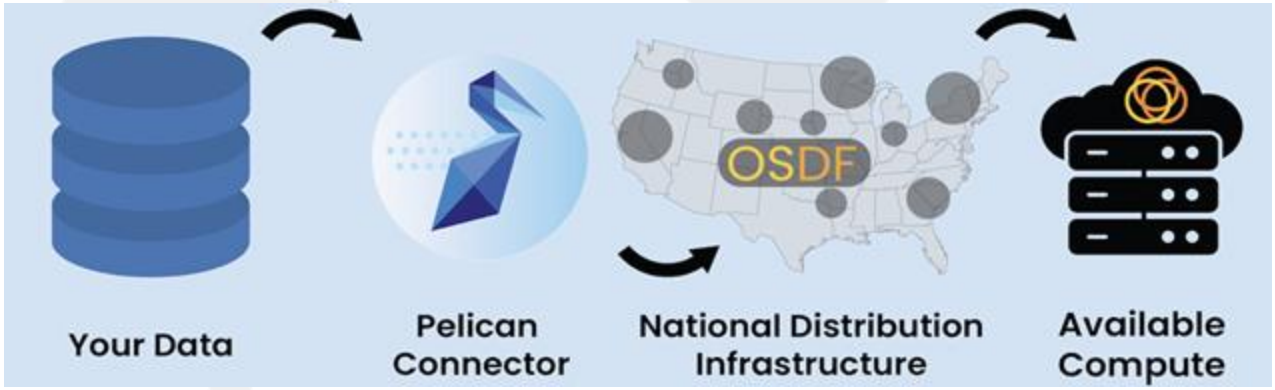
A highly abstracted view of what's inside an xrootd daemon when configured in XCache mode.

Pelican Reminder

The Pelican software powers the OSDF, a shared scientific data distribution infrastructure. A “CDN for science”.

Pelican relies on XCache to do the actual data movement.

- Hence, we need to ensure XCache fits well into the Pelican architecture.



Using XCache in Pelican

Pelican has some challenging aspects for XCache:

- All components speak HTTP, not necessarily XRootD.
  - (Particularly the director)
- Some origins are behind a firewall – no incoming connectivity.
- Pass through client-provided timeouts.

Q: How do we make XrdCl do all this “stuff”?
A: Use the XrdCl plugin mechanism!

The XrdCl Plugin

- One can provide a shared library that re-implements the XrdCl C++ API.
- For registered URLs, the shared library object is called instead of the default XrdCl code.
- Provided the implementation obeys the API “contract”, the shared library can have any desired behavior.
  - Let’s write a plugin for Pelican!

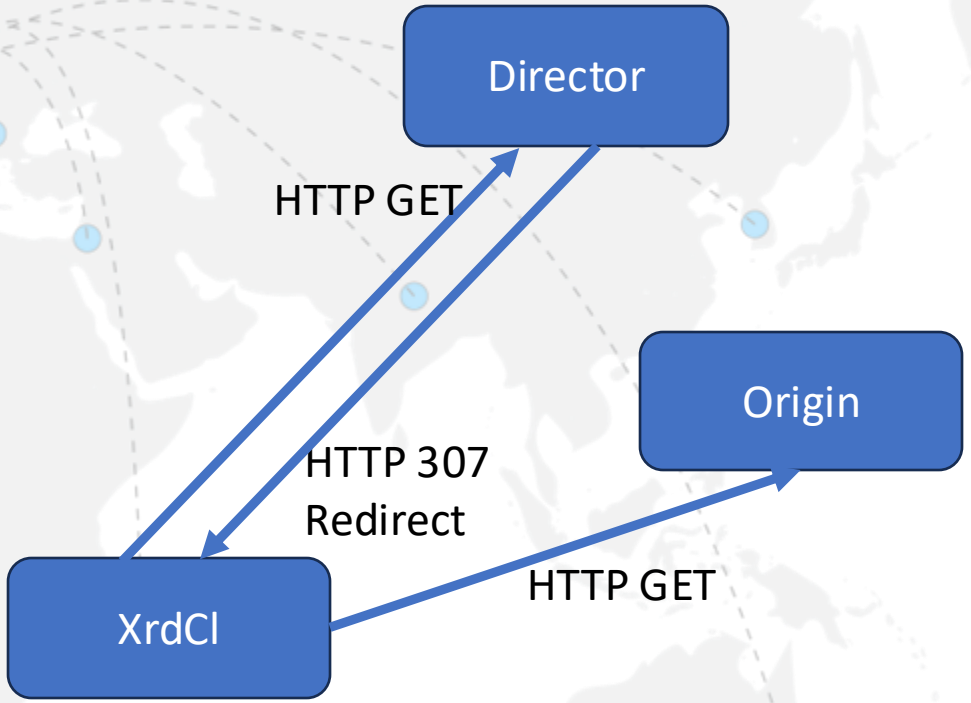
Example plugin configuration file contents:

```
url = pelican://*
lib = libXrdClPelican.dylib
enable = true
```

The above has libXrdClPelican.dylib used for any pelican:// URL.

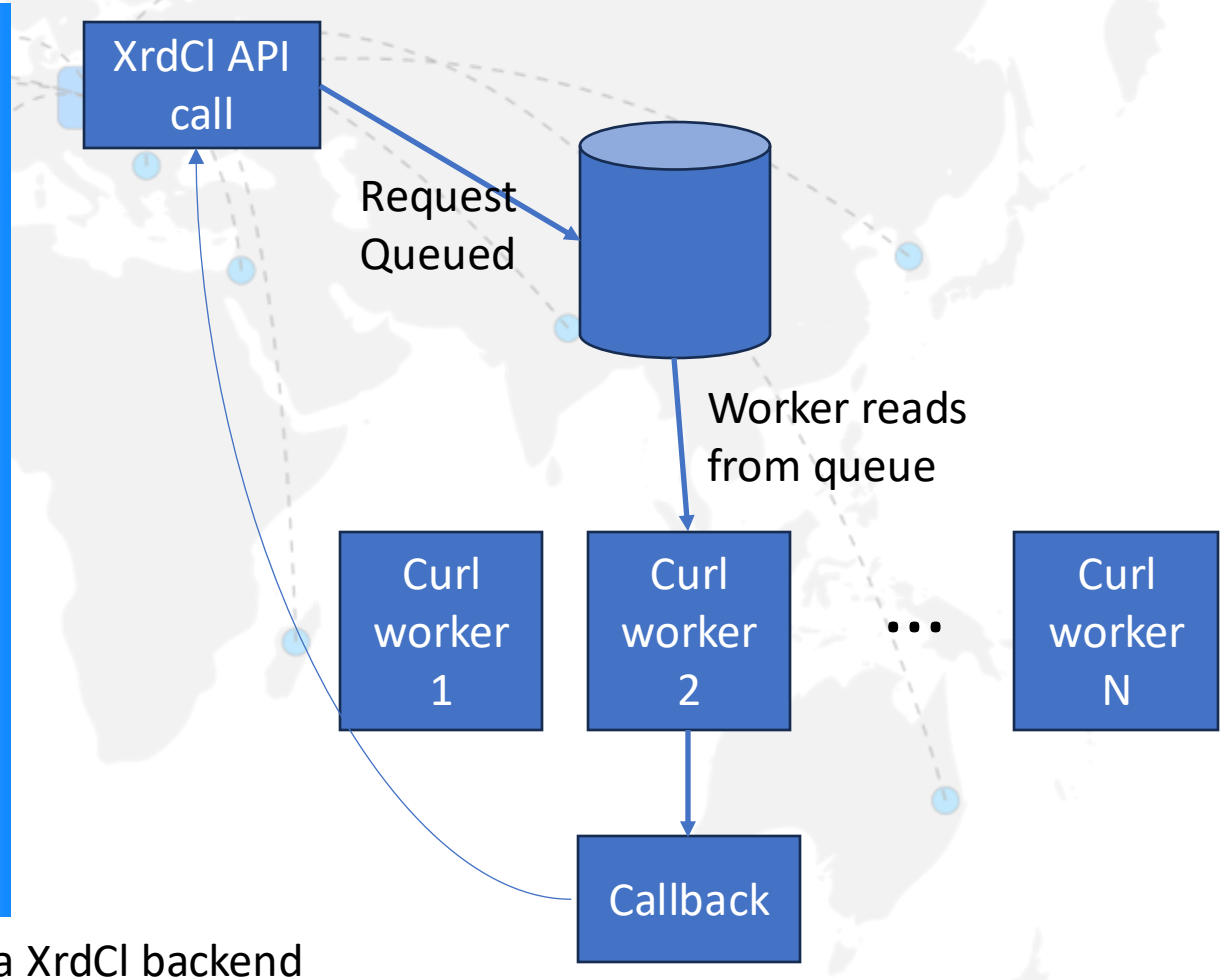
Pelican-izing XCache “Phase 1”

- Started by having the plugin invoke libcurl for file operations:
  - Open => HTTP GET sent to director, gets redirect to the origin.
  - Read => GET sent to origin
  - Stat => HEAD
  - Write => PUT (but not currently implemented)
- There’s a similar plugin, libXrdClHttp, that invokes Davix.



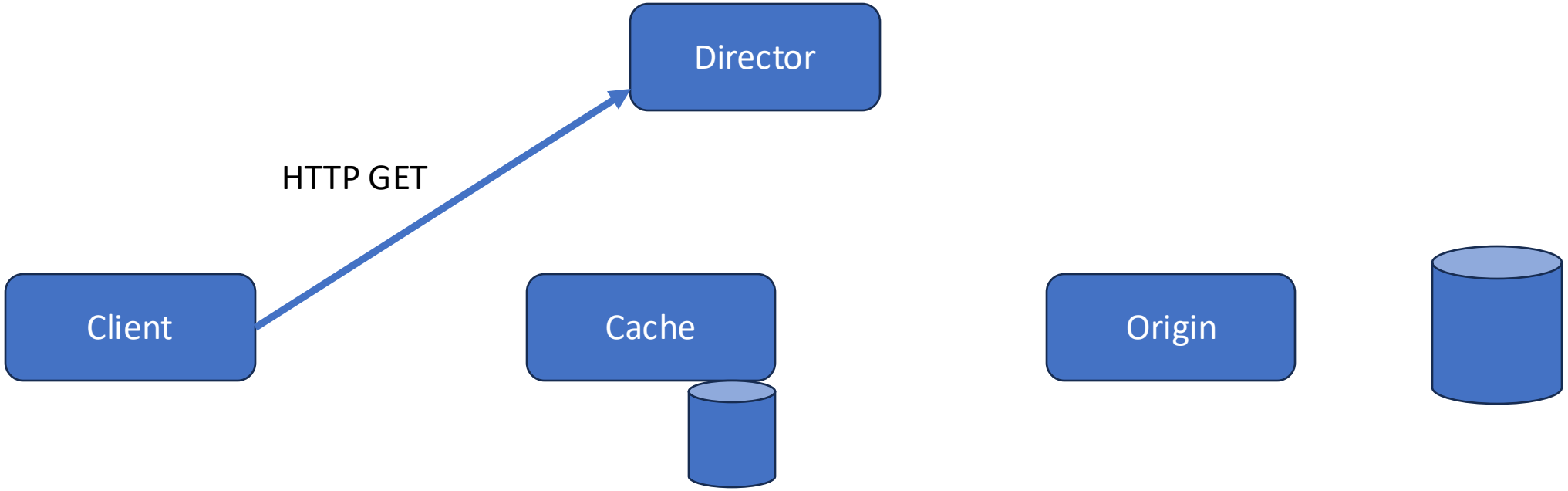
Pelican-izing XCache “Phase 1”

- Invoking libcurl directly reduces dependencies.
- We use the libcurl “multi” interface to have a single thread handle many transfers.
- By default, 5 worker threads
  - Concurrency is configurable
- When completed, the worker thread invokes the appropriate callback.
  - Hugely benefits from the fact XrdCl is asynchronous/callback-based.

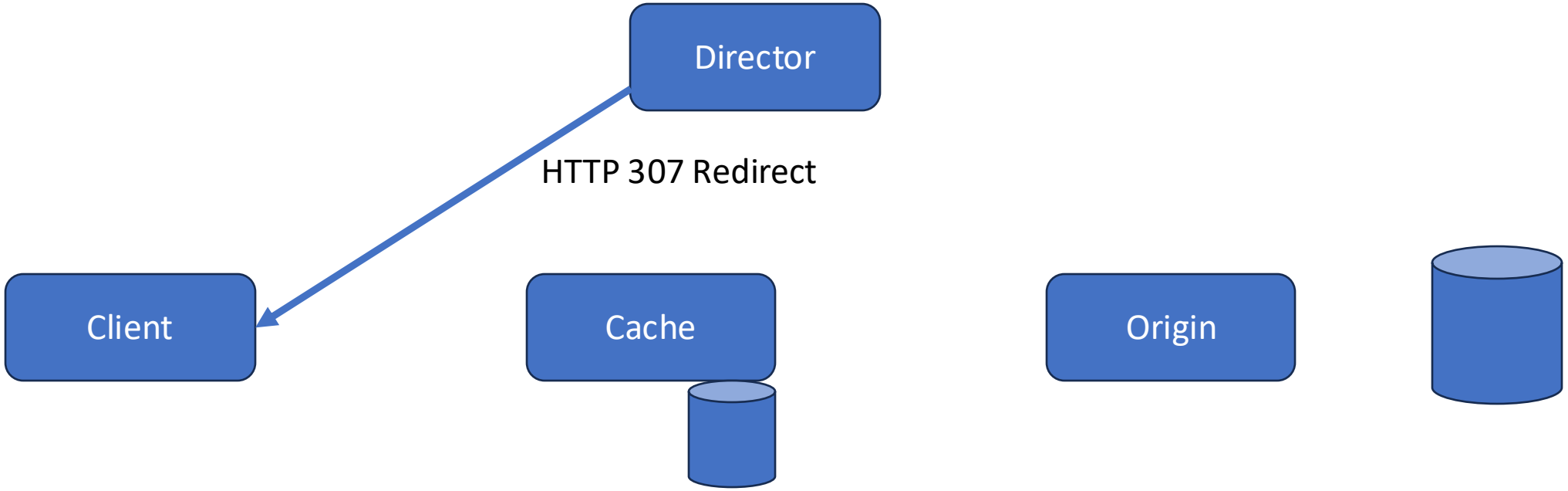


Great, we have a XrdCl backend for HTTP. Now what?

Plugin data flow



Plugin data flow



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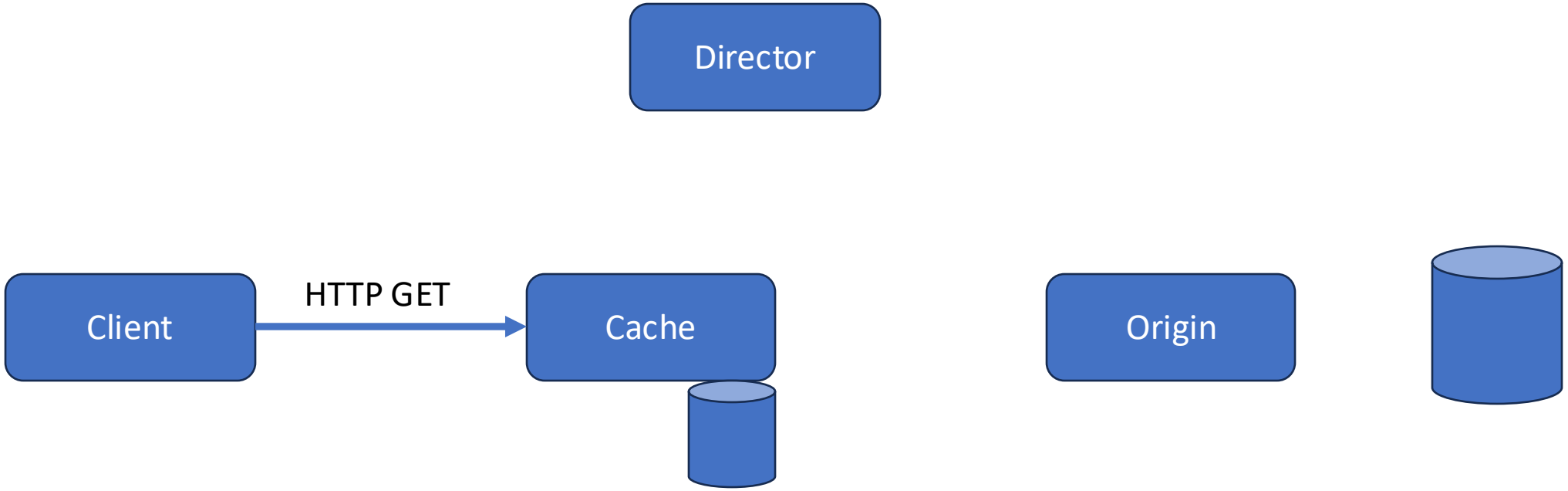

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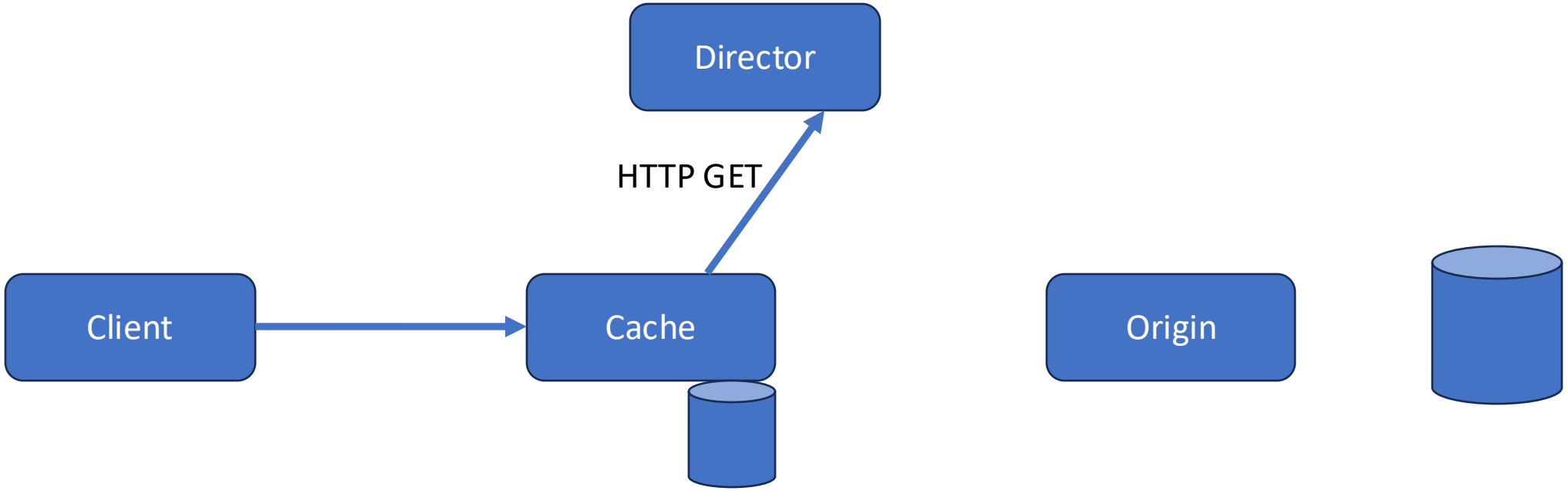

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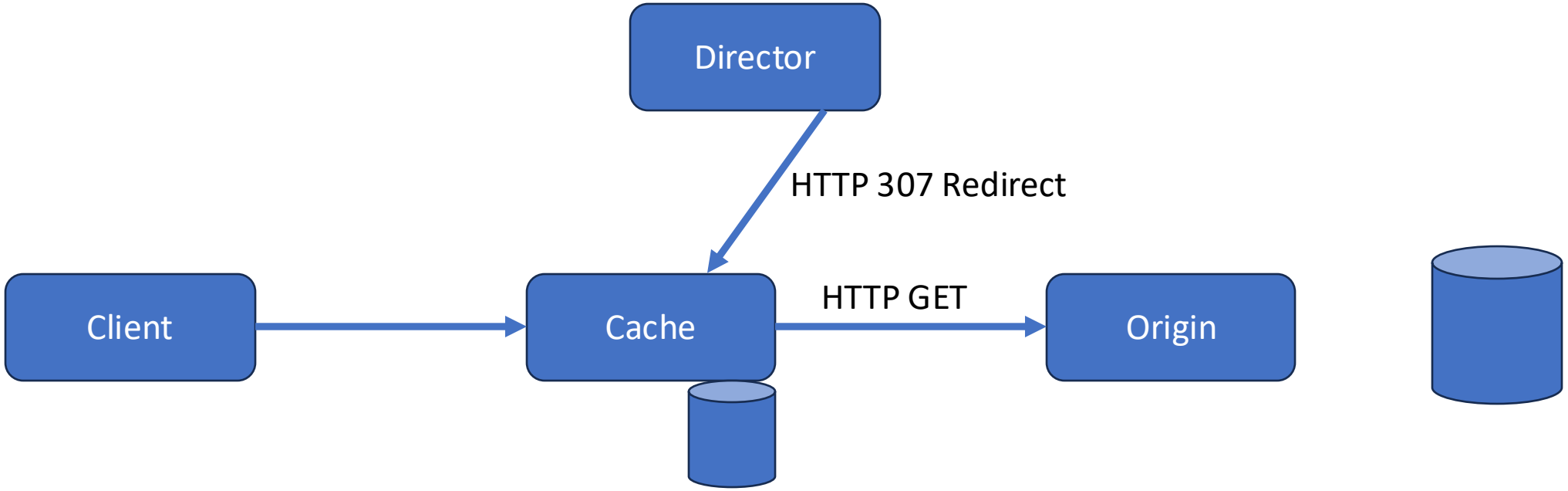

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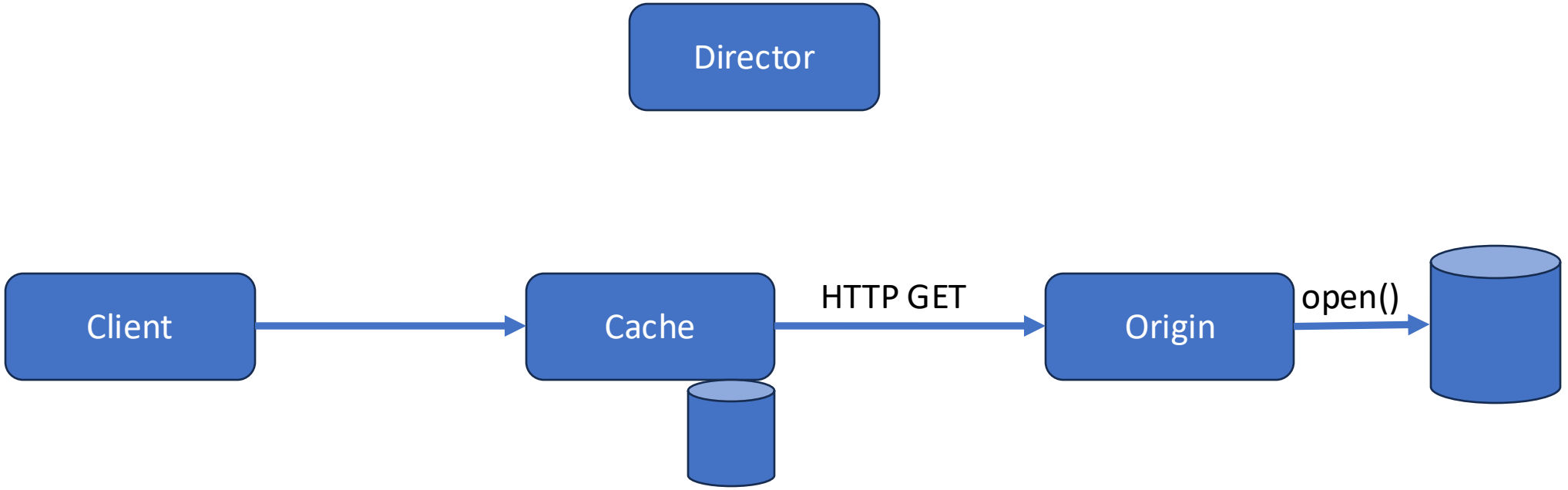
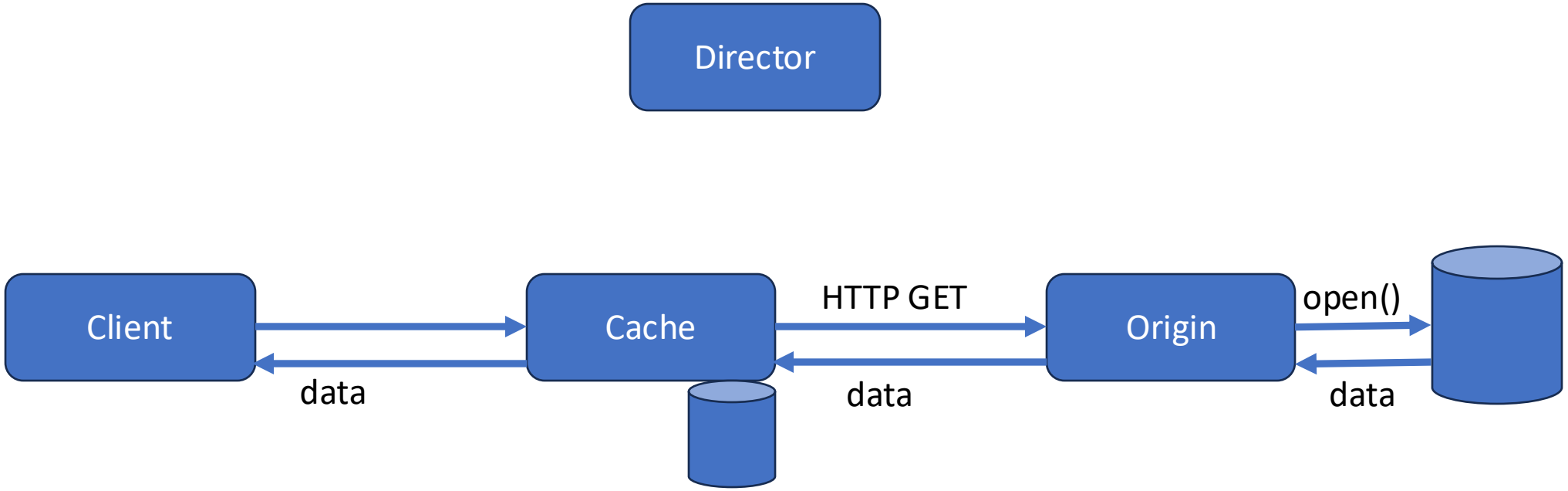


Plugin data flow



Note that the protocol between the client, cache, director, and origin is based on HTTP.

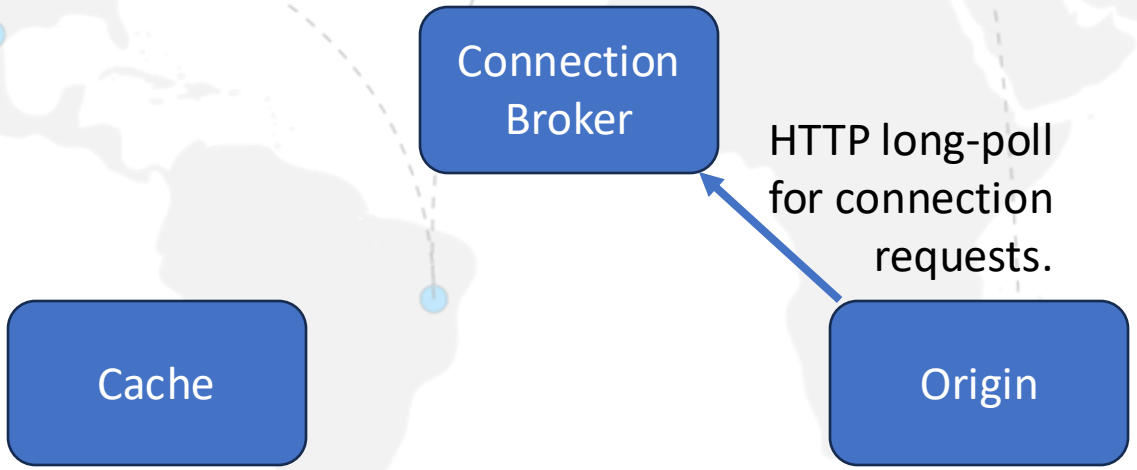
Next step – origins behind firewalls

- We want scientists to easily setup their own origin.
- Aspirational Goal:
  “I have a server in my lab and I want to share the data with my collaborators via OSDF”
- Aspirational Goal:
  Anyone with enough technical knowledge to setup a WiFi router can setup a Pelican origin.
- The average scientist doesn’t know how to:
  - Get a public IPv4 address for their lab.
  - Open an incoming port in the university firewall.
  - Setup a DNS entry.
  - Get a host certificate for their endpoint.

Get rid of these requirements!

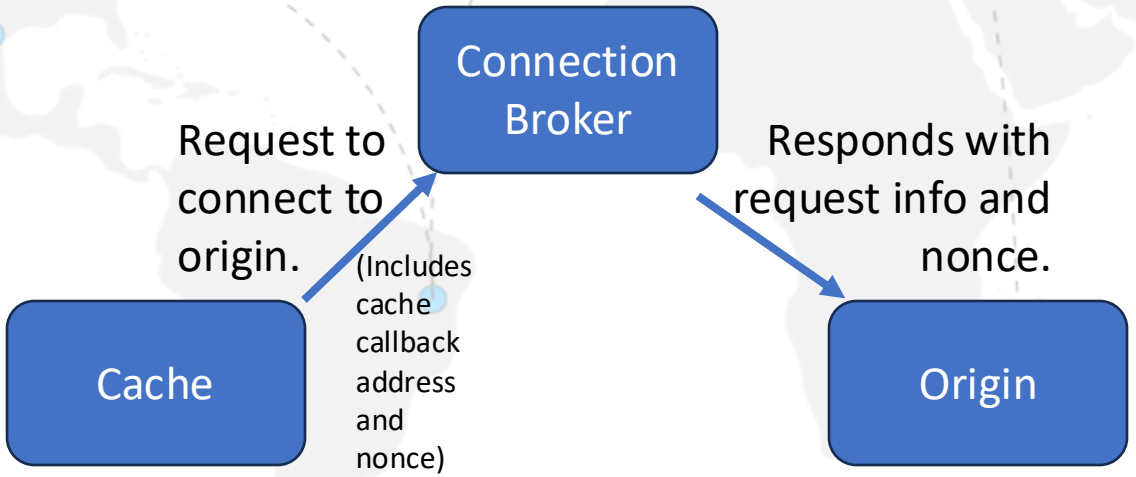
Connection Reversing

- Q: How do you host an origin without incoming connectivity?
  A: Connection Reversing!



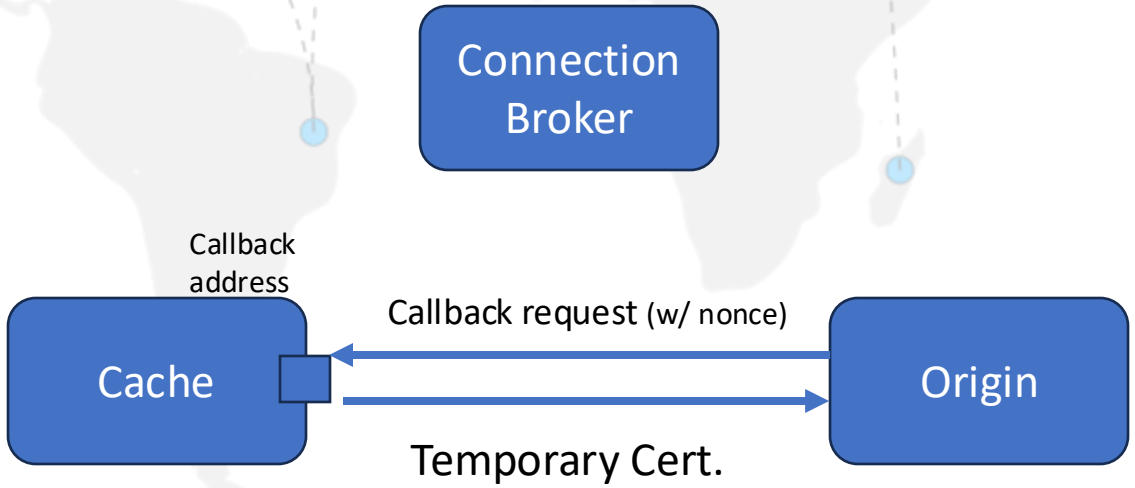
Connection Reversing

- Broker is the central agent to turn around requests.
  - Origin's outgoing poll either times out or retrieves a request.



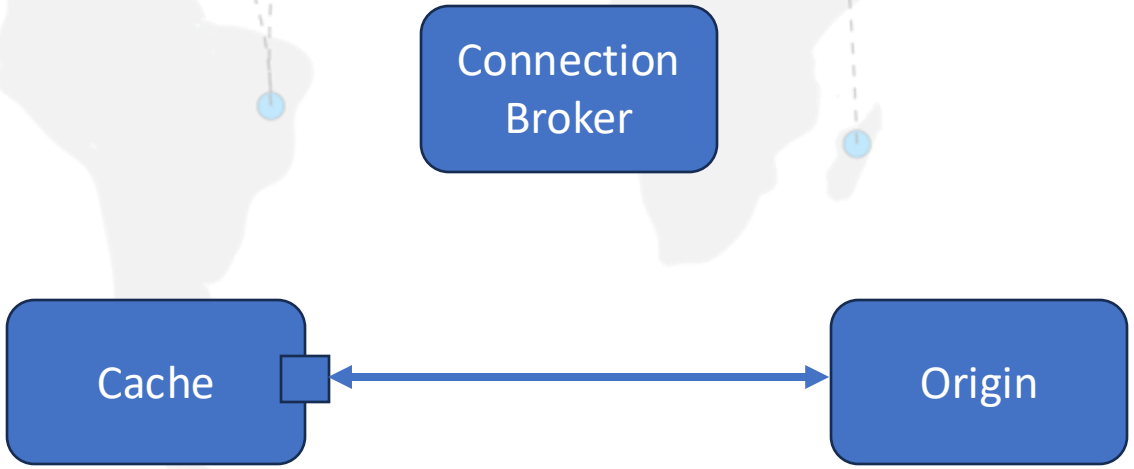
Connection Reversing

- The origin opens an outgoing connection to the cache.
  - To authenticate the request, sends the nonce it received from the broker.
  - The cache will generate a temporary host certificate and send it to the origin.



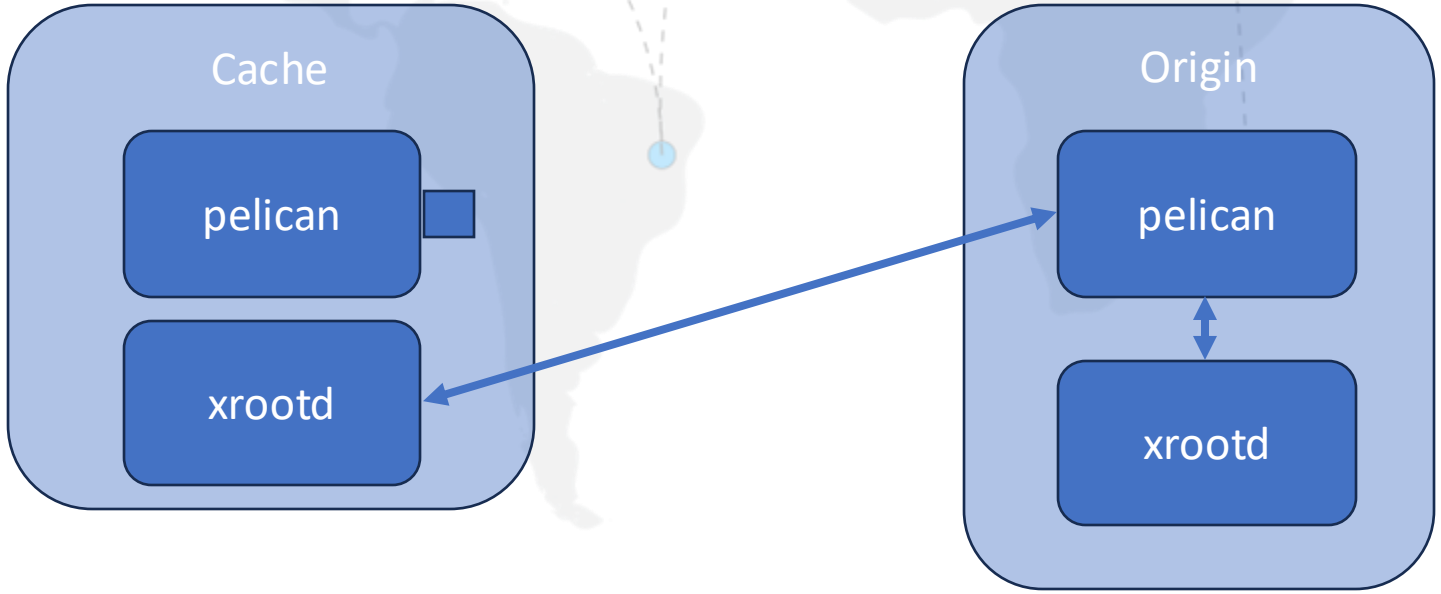
Connection Reversing

- Once the callback HTTP request has succeeded, we take advantage of the fact that an established TCP connection is bidirectional.
  - No difference between client and server!
  - Pretend it's a fresh connection and just treat it in reverse.
- The origin will use the temporary certificate it received (signed by the cache's self-signed CA) for future communication from the cache.



Connection Reversing

- Cache: Use Unix file descriptor passing to send the TCP connection from pelican to xrootd.
- Origin: Proxy requests from Pelican to xrootd.
- XrdCl plugin uses the TCP connection “normally” for HTTPS.



Connection Reversing – Putting it Together

- The XrdCl plugin gets a request for data.
- XrdCl plugin contacts the director, told the origin needs a connection reverse.
- XrdCl prepares and invokes a libcurl request.
- If libcurl doesn't have an existing TCP connection, it'll callback to the plugin to provide one.
  - The plugin will request a TCP connection from the pelican process.
  - Pelican will do the connection reversing and return a file descriptor.
  - The plugin returns the connected TCP socket to libcurl.
- Libcurl continues the request with the connected socket.

Handling client timeouts

- Q: Who is to blame for an unresponsive cache?
  - Is the cache overloaded or deadlocked?
  - Or is the cache fine and the origin unresponsive?
- Understanding if it's an "origin problem" or a "cache problem" greatly influences debugging and retry policies.
  - If it's an origin problem, then retrying at a different cache will likely only contribute to origin overload!
- **Idea**: Client should send, in its request, when it'll give up on the service.
  - If the cache is responsive but waiting on the origin, timeout the origin request and respond with "bad origin".

Request timeouts

- Client sets “X-Pelican-Timeout” header, e.g.
  - X-Pelican-Timeout: 10s
- Timeout is copied from header to the XRootD “cgi”:
  - /foo/bar?X-Pelican-Timeout=10s
- The XrdCl plugin gets the XRootD string and parses out the timeout
  - /foo/bar
  - Timeout: 10s
- The plugin will cancel the libcurl request prior to the timeout.
  - When timed out, the cache will return HTTP’s “502 Bad Gateway”.

Conclusions

- Pelican wants lots of custom behavior, different from the default XRootD / XCache experience.
  - But don't want to re-implement XCache! Many, many reasons to keep this component.
  - XrdCl plugins allow us to do keep XCache but also mix in our desired behavior.
- The existing plugin allows use of HTTP origins and connection-reversing.
- **Food for thought**: what's the difference between a XrdCl plugin that speaks HTTP and an OSS plugin that speaks HTTP?

See https://github.com/PelicanPlatform/xrdcl-pelican - have fun!

Questions?

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