Real-time HEP analysis with funcX:

A high-performance platform for function as a service

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What is funcX?

FuncX is an open-source platform which allows users to register, discover, and execute functions on arbitrary computing endpoints.

Users interact with funcX via a REST API exposed by an AWS-hosted funcX service.

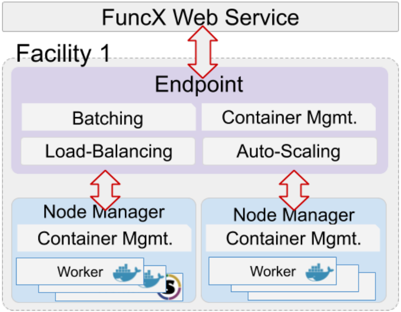
Note: What is described and evaluated in this talk is a prototype and under active development– stay tuned! If you’d like to try it out, contact me to be whitelisted.

What is a funcX endpoint?

FuncX endpoint: abstraction of a computational resource (a local machine, cluster, cloud, or supercomputer). The **endpoint agent** allows the funcX service to dispatch functions to that resource.

Admins or users can register and deploy an endpoint for themselves and/or others.

Scaling strategy can be customized to minimize latency (always keep a specified number of nodes provisioned) or to maximize efficiency (provision nodes in proportion to pending tasks).



A simple example: start an endpoint

1. Install funcX
2. Configure the endpoint (default configuration will run functions locally, or specify a Condor/Slurm/Torque/etc cluster, or specify AWS/Azure/GoogleCloud)
3. Authenticate and start endpoint

```
~ >pip install funcx==0.0.1a2
~ >funcx-endpoint configure my_endpoint
A default profile has been create for <my_endpoint> at /afs/crc.nd.edu/user/awoodard/.funcx/my_endpoint/config.py
Configure this file and try restarting with:
    > funcx-endpoint start my_endpoint
~ >funcx-endpoint start my_endpoint
It looks like this is the first time you're accessing this service.
Please log in to Globus at this link:
 https://auth.globus.org/v2/oauth2/authorize?client_id=4cf29807-cf21-49ec-9443-ff9a3fb9f81c&redirect_uri=[...]
Copy and paste the authorization code here: XXXXXXXXXXXXXXXXXXX
Thanks! You're now logged in.
2019-11-02 13:45:30 funcx:252 [INFO]  Endpoint registered with UUID: f8696260-c060-4f2b-814f-f5ba917f8472
```

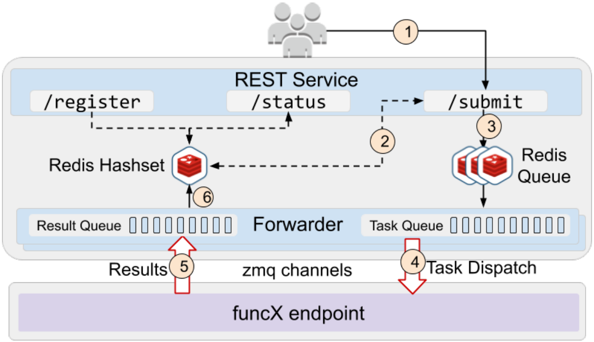
A simple example: run a function

```python
from funcx.sdk.client import FuncXClient

client = FuncXClient()

def compute_sum(items):
    return sum(items)

func_uuid = client.register_function(
    compute_sum,
    description="A sum function"
)

payload = [1, 2, 3, 4, 66]
endpoint_uuid = 'f8696260-c060-4f2b-814f-f5ba917f8472'
task_id = client.run(
    payload,
    endpoint_id=endpoint_uuid,
    function_id=func_uuid
)

result = client.get_result(task_id) # result is now 76
```

What happens when you execute a function?

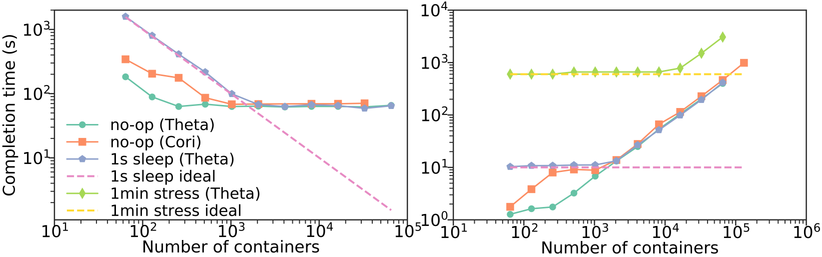
FuncX main components:

1. a registry of endpoints
2. a registry of functions (and optionally, associated containers)
3. a cloud-hosted system for management of function execution.



How does the funcX prototype scale?

Strong scaling: total concurrent functions fixed to 100k.
Weak scaling: functions per container fixed to 10.



(a) strong scaling (b) weak scaling

Scales to 130k+ containers; good performance up to ∼2k containers (1 second function) or ∼16k containers (1 minute function); similar performance using Singularity (on Theta) and Shifter (on Cori).

How can funcX speed up time-to-insight for physicists?

1. **Registry of functions+containers**[1] **reduces opportunities for users to make mistakes**

   Added bonuses: improve reproducibility, encourage modularity!
2. **Combine and utilize resources where they are available– backfill queues, non-dedicated campus clusters, etc**
3. **Scale interactive analysis in Jupyter notebooks**
4. **Use appropriate hardware where needed**

   For example: dispatch machine learning tasks to GPUs.
5. **Simple python SDK instead of writing submit scripts**

   Code to be executed is factorized from details of execution environment– to run somewhere else, simply swap out the endpoint UUID.

[1] Container support is currently being refactored in the prototype.

Show me the physics!

Case study: real-time HEP analysis with Coffea

Coffea[2] uses columnar operations to provide 1) an array-based syntax for manipulating HEP event data— implements histogramming, plotting, transformations, corrections, etc; and 2) a unified interface for writing executors which facilitate horizontal scaling.

To demonstrate how funcX can be used for real physics analyses, we wrote a funcX executor for Coffea[3].

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[2] Columnar Object Framework For Effective Analysis– check out their talk! `https://indico.cern.ch/event/773049/contributions/3476048/`

[3] Currently lives in a forked repo– will be merged after finalization: `https://github.com/annawoodard/coffea`

Case study: real-time HEP analysis with Coffea

The funcX coffea backend:

- Registers a function which takes input data and runs an analysis processor over it
- Transfers the analysis processor to each worker once and caches it
- Stages data out via XrootD (for now– more stageout methods can be added)
- Provides a convenience wrapper which chunks the data and submits a function for each chunk, then passes the results back to Coffea to combine into the final result histograms/counts

Case study: real-time HEP analysis with Coffea and funcX

```
~ > funcx-endpoint configure ndt3 --config config.py
~ > funcx-endpoint start ndt3
```

```python
import os

from funcx.config import Config
from funcx.strategies import SimpleStrategy
from parsl.providers import CondorProvider
from parsl.executors import HighThroughputExecutor
from parsl.addresses import address_by_hostname

proxy = '/tmp/x509up_u{}'.format(os.getuid())

worker_init = """
source /cvmfs/sft.cern.ch/lcg/views/LCG_95apython3/x86_64-centos7-gcc7-opt/setup.sh

export PATH=~/.local/bin:$PATH
export PYTHONPATH=~/.local/lib/python3.6/site-packages:$PYTHONPATH

export X509_USER_PROXY=`pwd`/{}
""".format(os.environ['USER'], os.path.basename(proxy))

config = Config(
    scaling_enabled=True,
    cores_per_worker=1,
    provider=CondorProvider(
        cores_per_slot=8,
        init_blocks=50,
        max_blocks=50,
        worker_init=worker_init,
        transfer_input_files=[proxy]
    ),
)
```

Step 1: start endpoints at Notre Dame and Wisconsin.

Case study: real-time HEP analysis with Coffea and funcX

```
import json

from coffea.processor import run_funcx_job
from coffea.processor.funcx.executor import funcx_executor

import funcx
funcx.set_file_logger('/afs/crc.nd.edu/user/a/awoodard/funcx.log')

ndt3_uuid = '81404f4b-9b35-4b92-9881-a02fe5e52693'
wisconsin_uuid = 'af21d0db-27f2-4906-beba-6baffac18393'
chunksize=750000

with open('metadata/samplefiles.json') as f:
    datasets = json.load(f)['Hbb_2017']

treenames = ['otree', 'Events']  # process mixed skims and full trees
stageout_path = 'root://deepthought.crc.nd.edu://store/user/awoodard/funcx'

final_accumulator = run_funcx_job(
    [ndt3_uuid, wisconsin_uuid],  # Add as many endpoints as you like!
    datasets,
    treenames,
    'boostedHbbProcessor.coffea',
    funcx_executor,
    stageout_path,
    executor_args=executor_args,
    chunksize=chunksize
)
```

Step 2: find a real physics analysis to run– we borrowed from the coffeaandbacon $H \to bb$ analysis[4].

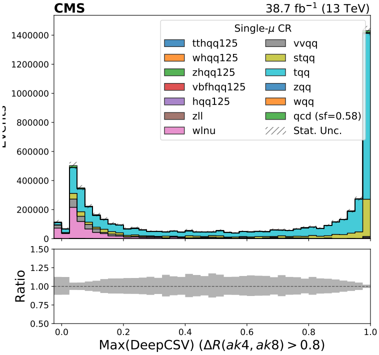
Step 3: pass their analysis processor (defines analysis selections, weights, and histograms) and datasets to the `run_funcx_job` wrapper[5].

[4] `https://github.com/nsmith-/coffeandbacon`

[5] For full Jupyter notebooks, see

`https://github.com/annawoodard/coffeandbacon/blob/master/analysis/baconbits-funcx.ipynb`

`https://github.com/annawoodard/coffeandbacon/blob/master/analysis/baconbits-plot.ipynb`



Analysis code from `https://github.com/nsmith-/coffeandbacon`

Result: processed ~291 million events (nanoAOD format) in 9 minutes (1.9 µs/event) on ~400 cores[4], combining resources from two separate sites.

[4] Compare with 7.6 minutes (1.6 µs/event) on ~400 cores with Parsl

Conclusions

- FuncX is an open-source platform which allows users to decompose applications into collections of functions that can each be executed in the best location (in terms of cost/execution time/resource availability), on endpoints managed by users or admins
- FuncX's registry of functions+containers can improve modularity and reproducibility in user code
- We've implemented a funcX processing backend for the Coffea analysis framework and demonstrated good performance while integrating computing resources from multiple sites

Keep in touch!

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`https://funcx.readthedocs.io`

(UNDER CONSTRUCTION)

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