IETF Hackathon

Application Layer Traffic Optimization (ALTO) WG

Using ALTO Cost-Maps to Optimize Dataset Transfer for LHC

Presenter: Jordi Ros-Giralt on behalf of ALTO WG

IETF 113
19-20 March 2022
Vienna, Austria

Thank you to all participants:

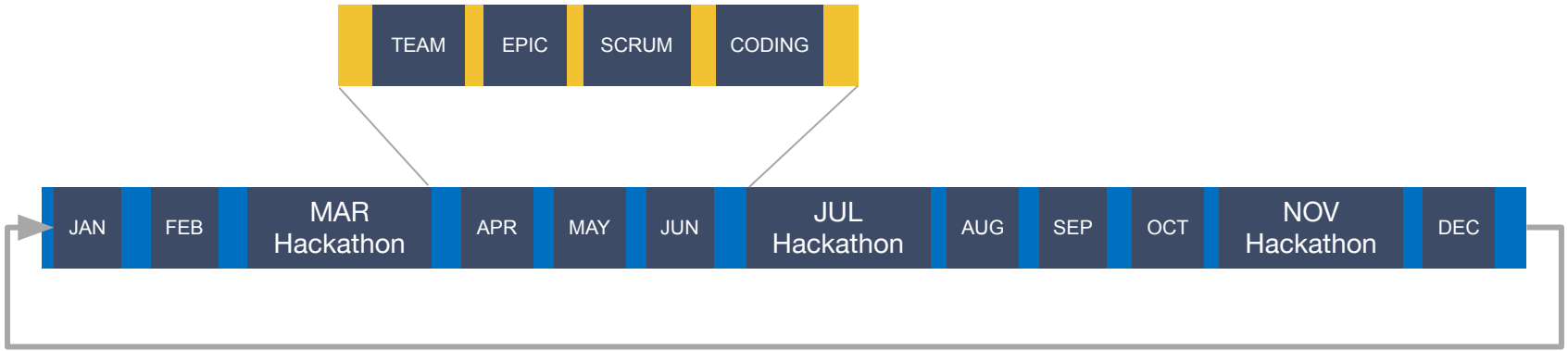
Jensen Zhang, Kai Gao, Jordi Ros-Giralt, Y. Richard Yang, Mahdi Soleimani, John Graham, Radu Carpa, Alex Briasco-stewart, Mario Lassnig, Martin Barisits, Harvey Newman, Jacob Dunefsky, Sruthi Yellamraju, Bingcheng Wang, Evan Visher, Donglin Han, Dong Guo.

And all the members from the ALTO WG, Yale, Tongji and Sichuan Universities, the Pacific Research Platform in California and the CERN Rucio (LHC) team in Switzerland, and companies involved in the WG activities.

Working endless hours managing 3 time zones! (US, EU, China) for the Hackathon.

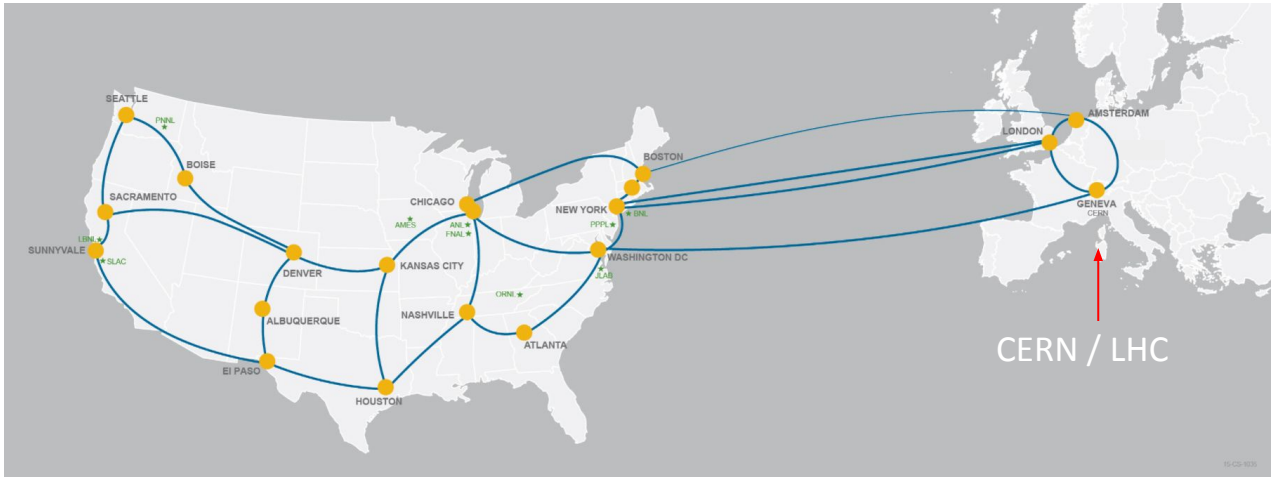
OpenALTO: Continuous Integration with Hackathon Checkpoints

- The ALTO Code Base Project aims at providing a parallel track to the WG's standardization effort towards implementing the features introduced in the latest RFCs.
- IETF Hackathons will be used as 3-checkpoints a year to test interoperability, demo latest standard capabilities and identify issues and improvements for standardization.
- Identify and build production, open-source environments for use cases and deployment ("lean startup") to help steer ALTO standardization.



Goals in this Hackathon

- Use ALTO Cost Maps to optimize dataset transfers for rucio, the main data management tool for LHC and other large projects.
- Integrate ALTO Northbound Interface with Rucio to provide visibility and achieve better performance.
- Show that it works.



* ESnet / LHCONE source: https://www.es.net/about/

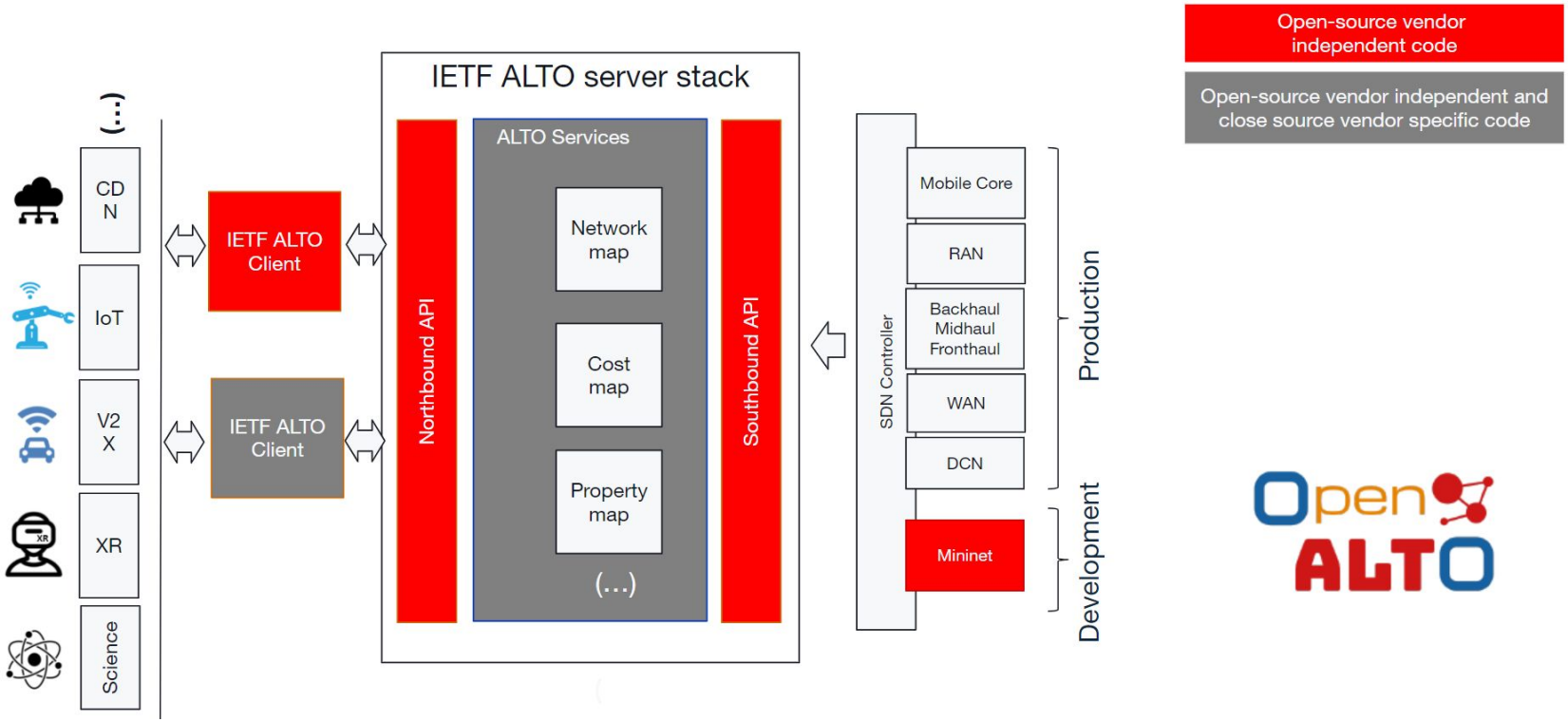
RFCs Involved During the Hackathon

- RFC 7285: Application-Layer Traffic Optimization (ALTO) Protocol
  https://datatracker.ietf.org/doc/rfc7285/
- I-Draft ALTO Extension: Flow-based Cost Query
  https://datatracker.ietf.org/doc/draft-gao-alto-fcs/
- I-Draft ALTO Performance Cost Metrics
  https://datatracker.ietf.org/doc/draft-ietf-alto-performance-metrics/

What Got Done

- Implementation of an ALTO Client in Python (RFC 7285)
- Integration with CERN Rucio replica download
  - Submitted pull request to Rucio Project: https://github.com/rucio/rucio/pull/5364
- 3 Demos [https://github.com/openalto/ietf-hackathon/issues/8]
  - [D1] Single-flow replica node selection using ALTO BW Cost Map
  - [D2] ALTO Estimator: Multi-flow BW prediction
  - [D3] ALTO Scheduler: SLA-constrained multi-flow node selection
- Southbound ALTO integration with SDN:
  - Mininet/Pox, OpenDaylight
- Scrum dashboard: https://github.com/orgs/openalto/projects/1/views/1
- Lots of really interesting architecture discussions

OpenALTO Project [https://github.com/openalto/]



ALTO Metrics

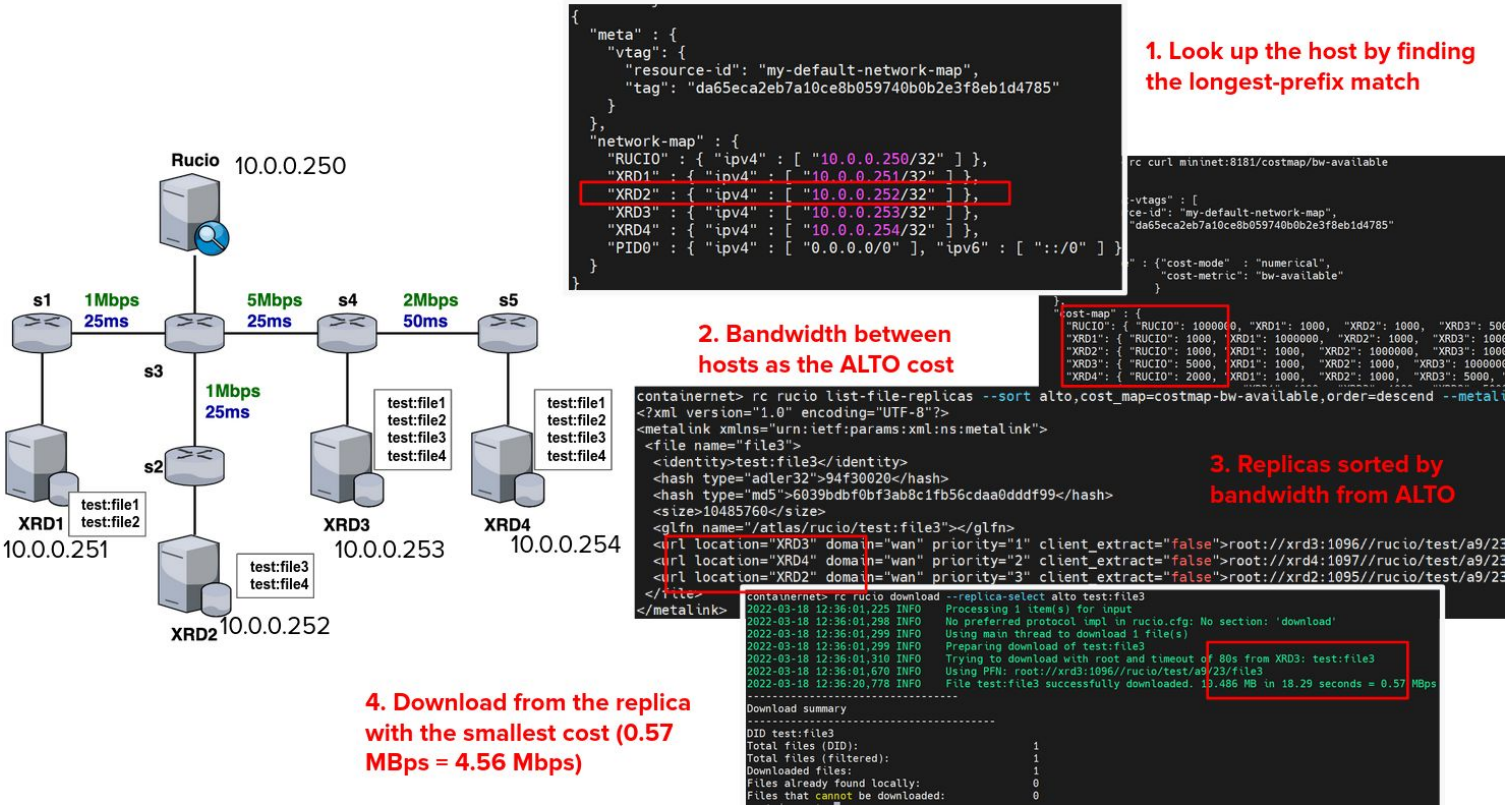
https://datatracker.ietf.org/doc/draft-ietf-alto-performance-metrics/

Metric	Definition in this doc	Semantics Based On
One-way Delay	Section 3.1	Base: [RFC7471,8570,8571] sum Unidirectional Delay
Round-trip Delay	Section 3.2	Base: Sum of two directions from above
Delay Variation	Section 3.3	Base: [RFC7471,8570,8571] sum of Unidirectional Delay Variation
Loss Rate	Section 3.4	Base: [RFC7471,8570,8571] sum Unidirectional Link Loss
Residual Bandwidth	Section 4.2	Base: [RFC7471,8570,8571] min Unidirectional Residual BW
Available Bandwidth	Section 4.3	Base: [RFC7471,8570,8571] min Unidirectional Avail. BW
Utilized Bandwidth	Section 4.4	Base: [RFC7471,8570,8571] max Unidirectional Utilized BW
TCP Throughput	Section 4.1	[RFC8312bis]
Hop Count	Section 3.5	[RFC7285]

Table 1. Cost Metrics Defined in this Document.

Metrics used in this hackathon

Demo 1: Single-flow Replica Node Selection Using ALTO BW Cost Map

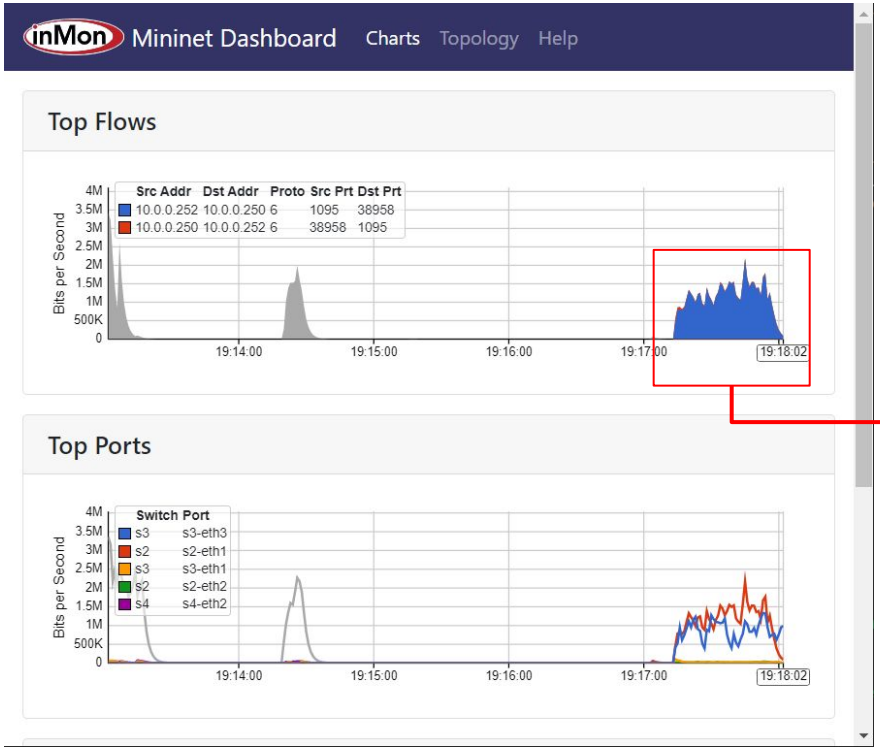


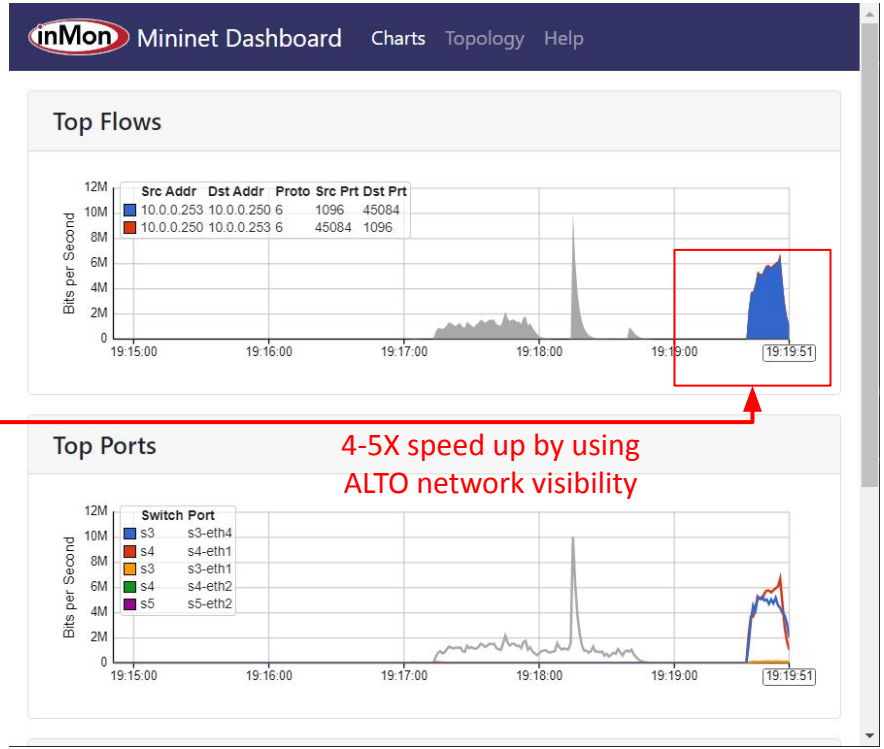

```
{
  "meta" : {
    "vtag": {
      "resource-id": "my-default-network-map",
      "tag": "da65eca2eb7a10ce8b059740b0b2e3f8eb1d4785"
    }
  },
  "network-map" : {
    "RUCIO" : { "ipv4" : [ "10.0.0.250/32" ] },
    "XRD1" : { "ipv4" : [ "10.0.0.251/32" ] },
    "XRD2" : { "ipv4" : [ "10.0.0.252/32" ] },
    "XRD3" : { "ipv4" : [ "10.0.0.253/32" ] },
    "XRD4" : { "ipv4" : [ "10.0.0.254/32" ] },
    "PID0" : { "ipv4" : [ "0.0.0.0/0" ], "ipv6" : [ "::/0" ] }
  }
}
```


```
containernet> rc rucio list-file-replicas --sort alto,cost_map=costmap-bw-available,order=descend --metali
<?xml version="1.0" encoding="UTF-8"?>
<metalink xmlns="urn:ietf:params:xml:ns:metalink">
 <file name="file3">
  <identity>test:file3</identity>
  <hash type="adler32">94f30020</hash>
  <hash type="md5">6039bdbf0bf3ab8c1fb56cdaa0dddf99</hash>
  <size>10485760</size>
  <glfn name="/atlas/rucio/test:file3"></glfn>
  <url location="XRD3" domain="wan" priority="1" client_extract="false">root://xrd3:1096//rucio/test/a9/23
  <url location="XRD4" domain="wan" priority="2" client_extract="false">root://xrd4:1097//rucio/test/a9/23
  <url location="XRD2" domain="wan" priority="3" client_extract="false">root://xrd2:1095//rucio/test/a9/23
 </file>
</metalink>
```

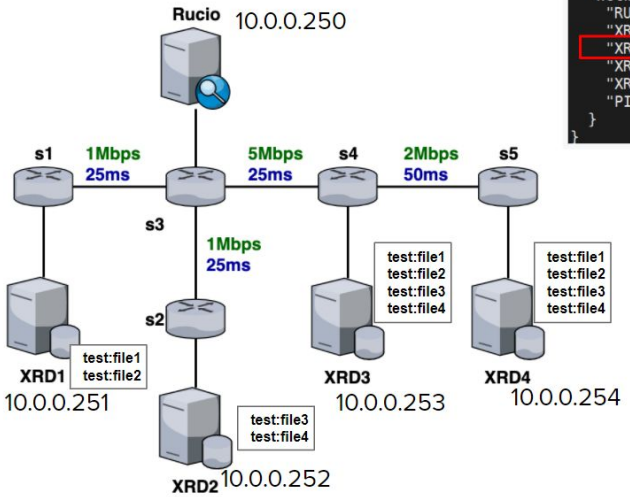
```
containernet> rc rucio download --replica-select alto test:file3
2022-03-18 12:36:01,225 INFO    Processing 1 item(s) for input
2022-03-18 12:36:01,298 INFO    No preferred protocol impl in rucio.cfg: No section: 'download'
2022-03-18 12:36:01,299 INFO    Using main thread to download 1 file(s)
2022-03-18 12:36:01,299 INFO    Preparing download of test:file3
2022-03-18 12:36:01,310 INFO    Trying to download with root and timeout of 80s from XRD3: test:file3
2022-03-18 12:36:01,670 INFO    Using PFN: root://xrd3:1096//rucio/test/a9/23/file3
2022-03-18 12:36:20,778 INFO    File test:file3 successfully downloaded. 10.486 MB in 18.29 seconds = 0.57 MBps
---------------------------------------
Download summary
---------------------------------------
DID test:file3
Total files (DID):                      1
Total files (filtered):                 1
Downloaded files:                       1
Files already found locally:            0
Files that cannot be downloaded:        0
```

Demo 1: Single-flow Replica Node Selection Using ALTO BW Cost Map





Demo 1: Single-flow Replica Node Selection Using ALTO Latency Cost Map




```
{
  "meta" : {
    "vtag": {
      "resource-id": "my-default-network-map",
      "tag": "da65eca2eb7a10ce8b059740b0b2e3f8eb1d4785"
    }
  },
  "network-map" : {
    "RUCIO" : { "ipv4" : [ "10.0.0.250/32" ] },
    "XRD1" : { "ipv4" : [ "10.0.0.251/32" ] },
    "XRD2" : { "ipv4" : [ "10.0.0.252/32" ] },
    "XRD3" : { "ipv4" : [ "10.0.0.253/32" ] },
    "XRD4" : { "ipv4" : [ "10.0.0.254/32" ] },
    "PID0" : { "ipv4" : [ "0.0.0.0/0" ], "ipv6" : [ "::/0" ] }
  }
}
```


1. Look up the host by finding the longest-prefix match

```
rc curl mininet:8181/costmap/delay-ow


-vtags" : [
ce-id": "my-default-network-map",
"da65eca2eb7a10ce8b059740b0b2e3f8eb1d4785"


" : {"cost-mode"  : "numerical",
    "cost-metric": "delay-ow"
  }

{
  "RUCIO": { "RUCIO": 0, "XRD1": 25,  "XRD2": 25,  "XRD3": 25, "XRD4": 75, "PID0": 0
  "XRD1": { "RUCIO": 25, "XRD1": 0,   "XRD2": 50,  "XRD3": 50, "XRD4": 100, "PID0": 2
  "XRD2": { "RUCIO": 25, "XRD1": 50,  "XRD2": 0,   "XRD3": 50, "XRD4": 100, "PID0": 2
  "XRD3": { "RUCIO": 25, "XRD1": 50,  "XRD2": 50,  "XRD3": 0,  "XRD4": 50, "PID0": 25
  "XRD4": { "RUCIO": 75, "XRD1": 100,  "XRD2": 100,  "XRD3": 50, "XRD4": 0, "PID0":
  PID0": { "RUCIO": 0, "XRD1": 25,  "XRD2": 25,  "XRD3": 25, "XRD4": 75, "PID0": 0
```

2. One-way latency between hosts as the ALTO cost

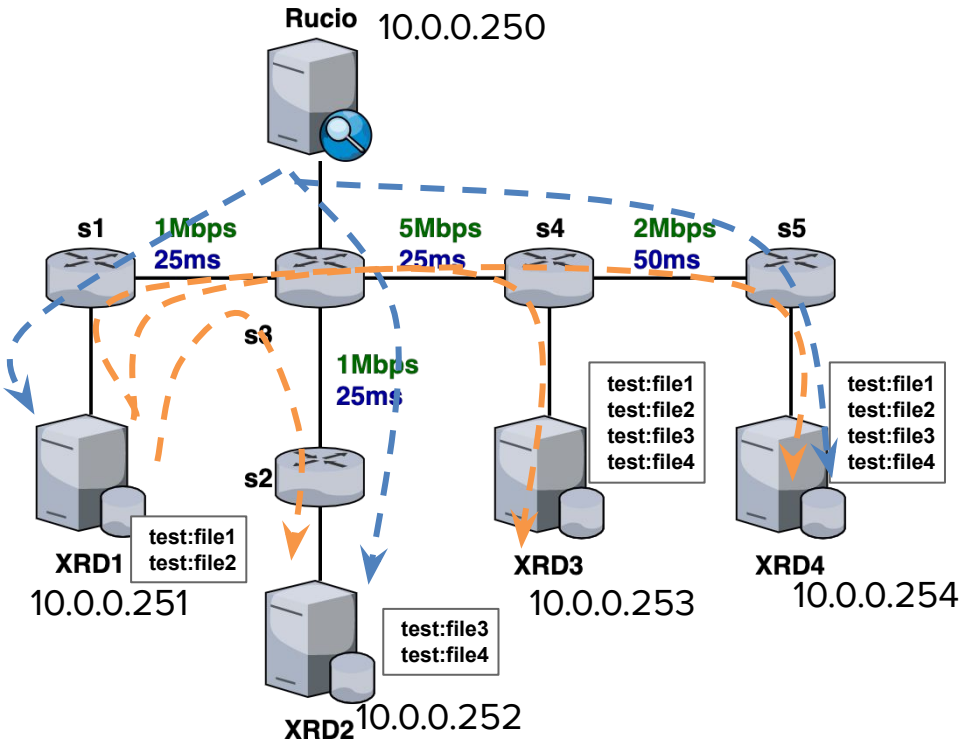
```
containernet> rc rucio list-file-replicas --sort alto,cost_map=costmap-delay-ow --metalink test:file3
<?xml version="1.0" encoding="UTF-8"?>
<metalink xmlns="urn:ietf:params:xml:ns:metalink">
 <file name="file3">
  <identity>test:file3</identity>
  <hash type="adler32">94f30020</hash>
  <hash type="md5">6039bdbf0bf3ab8c1fb56cdaa0dddf99</hash>
  <size>10485760</size>
  <glfn name="/atlas/rucio/test:file3"></glfn>
  <url location="XRD2" domain="wan" priority="1" client_extract="false">root://xrd2:1095//rucio/test/
  <url location="XRD3" domain="wan" priority="2" client_extract="false">root://xrd3:1096//rucio/test/
  <url location="XRD4" domain="wan" priority="3" client_extract="false">root://xrd4:1097//rucio/test/
 </file>
</metalink>
```

3. Replicas sorted by latency from ALTO

```
2022-03-20 11:16:51,737 INFO    No preferred protocol impl in rucio.cfg: No section: 'download'
2022-03-20 11:16:51,738 INFO    Using main thread to download 1 file(s)
2022-03-20 11:16:51,738 INFO    Preparing download of test:file3
2022-03-20 11:16:51,755 INFO    Trying to download with root and timeout of 80s from XRD2: test:file3
2022-03-20 11:17:02,569 INFO    Using PFN: root://xrd2:1095//rucio/test/a9/23/file3
2022-03-20 11:18:42,144 INFO    File test:file3 successfully downloaded. 10.486 MB in 98.75 seconds = 0.11 MBps
---------------------------------
Download summary
---------------------------------
DID test:file3
Total files (DID):                      1
Total files (filtered):                 1
```

4. Download from the replica with the smallest latency

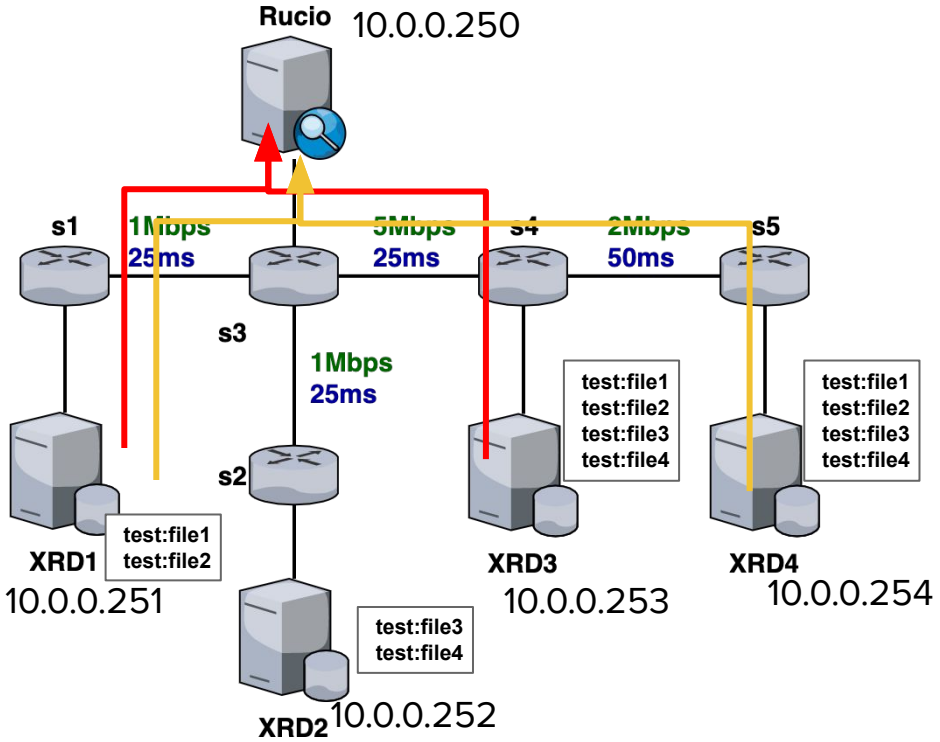
Demo 2: ALTO Estimator: Multi-flow Tput/BW Prediction




```
containernet> rc alto-estimator --alto-server http://minin
et:8181 --flows /opt/alto/tests/bwest/flows.demo | python3
 -m json.tool
{
    "meta": {
        "cost-type": {
            "cost-mode": "numerical",
            "cost-metric": "tput"
        }
    },
    "endpoint-cost-map": {
        "ipv4:10.0.0.250": {
            "ipv4:10.0.0.251": 0.2221213202250089,
            "ipv4:10.0.0.252": 0.4420177233358019,
            "ipv4:10.0.0.254": 0.335860959248392
        },
        "ipv4:10.0.0.251": {
            "ipv4:10.0.0.252": 0.2738144686147328,
            "ipv4:10.0.0.253": 0.2738145448368706,
            "ipv4:10.0.0.254": 0.23024966972090757
        }
    }
}
```

TCP throughput computed from network topology and TCP throughput modeling for bulk flows ([G2, PROPHET]).

Demo 3: ALTO Scheduler: SLA-constrained Multi-flow Node Selection



- Problem
  - Multiple datasets replicated on multiple hosts.
  - Rucio dataset automation workflow requires a given SLA (e.g., time-bound constrained data transfers)
- Demo **(partially finished)**
  - ALTO ESTIMATOR (Demo) provides cost map predicting replication throughput
  - ALTO SCHEDULER searches among possible download configuration one that guarantees the SLA requirement.

Example:
- Goal: download datasets file1, file3
- Replica selections: red versus yellow. Pick one replica that satisfies the SLA.

Wrap Up and Looking Forward

- **ALTO WG Contact:**
  - IETF ALTO WG: https://datatracker.ietf.org/wg/alto/about/
- **ALTO Code Base Project:**
  - Repo: https://github.com/openalto/
  - IETF Hackathon 113 ALTO Scrum Dashboard: https://github.com/orgs/openalto/projects/1/views/1
- **Potential Tasks/demos at IETF 114 hackathon:**
  - Finishing Demo 3, ALTO with HTTP/2
  - ALTO for multiple experiments for Rucio and more production use cases
- **Want to contribute to OpenALTO as a developer?** Reach us out: **jros at qti.qualcomm.com**

Looking forward to seeing you in Philadelphia!

Paper References

[G2] Jordi Ros-Giralt, Noah Amsel, Sruthi Yellamraju, James Ezick, Richard Lethin, Yuang Jiang, Aosong Feng, Leandros Tassiulas, Zhenguo Wu, Min Yeh Teh, Keren Bergman, "Designing Data Center Networks Using Bottleneck Structures," ACM SIGCOMM, New York, August 2021.

[PROPHET] J. Zhang, K. Gao, Y. R. Yang and J. Bi, "Prophet: Toward Fast, Error-Tolerant Model-Based Throughput Prediction for Reactive Flows in DC Networks," in IEEE/ACM Transactions on Networking, vol. 28, no. 6, pp. 2475-2488, Dec. 2020, doi: 10.1109/TNET.2020.3016838.