NDN FOR DATA INTENSIVE SCIENCE - SANDIE

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The “big-data” problem

- The LHC is world’s largest data intensive application (1 Exabyte data by the end of 2018)
- LHC network connects CERN to ~500 tiered sites worldwide
- Demand is growing in multiple dimensions
  - Number of datasets
  - Complexity of data
  - Global collaborations
  - Network traffic
- Present infrastructure can not scale to meet the needs of LHC Run3 (2021-23)

The SANDIE Project

- Uses NDN principles to enhance LHC network and data distribution capabilities
- Deploy caches at strategic points (both at the core and the edge)
- Integrate NDN-based backend with existing software infrastructure
  - Simplify and add new capabilities
- Deploy large scale testing infrastructures
  - SSD based caches + large disk based caches
  - Extend CSU testbed, add 40G/100G networks at 7 sites
  - Support transactions that may require upto 10TB or more data

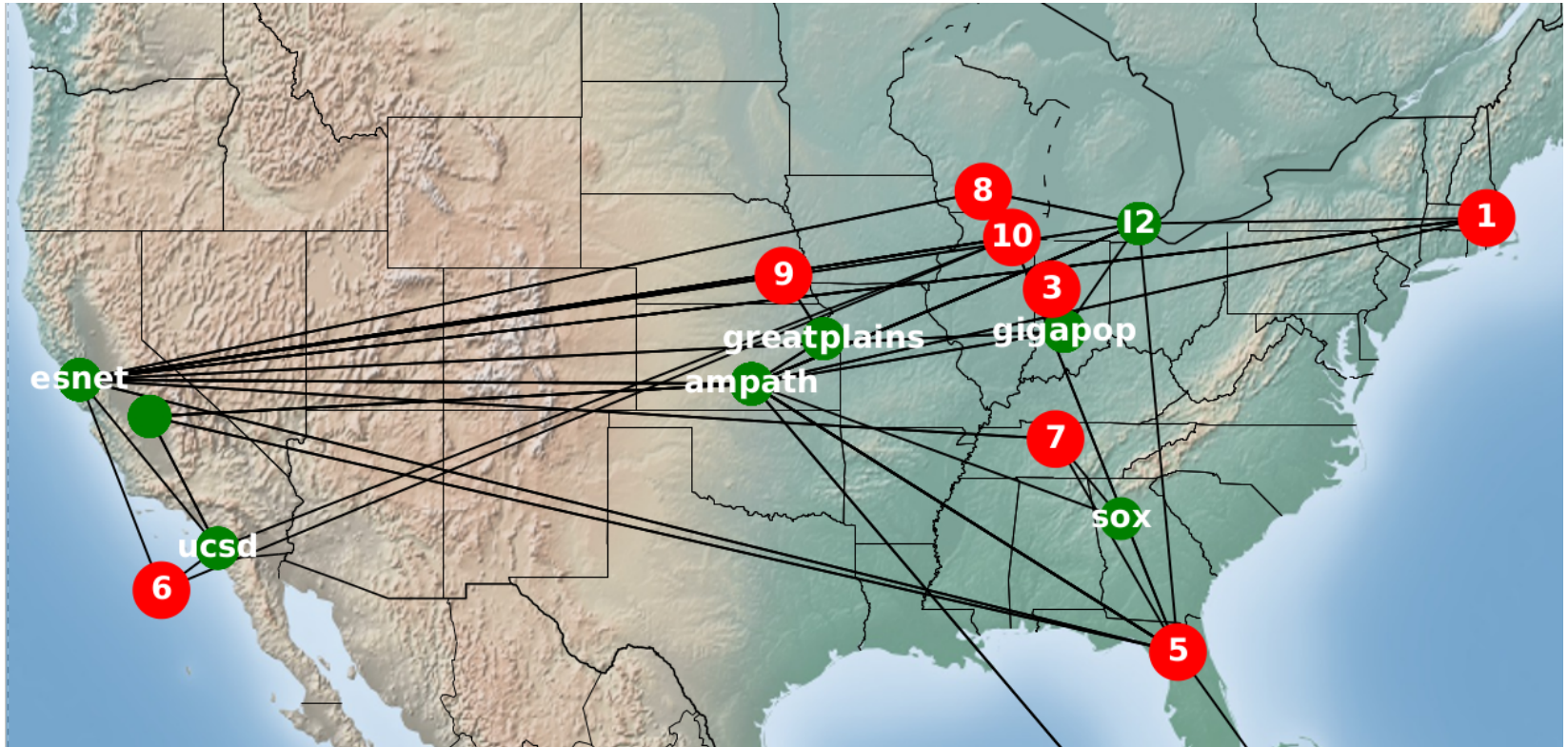
A Global Testbed

- Expand CSU climate testbed and CalTech SDN testbed
- Deploy few more sites across the USA, Europe, and India
- Caches each with
  - Several terabytes of SSDs
  - 40-60 Terabytes of SAS disks
  - 10G to 100G network interfaces
  - NDN and Xrootd software systems
- New nodes already deployed at CalTech/NEU

Testing the Potential for NDN’s Improvements

CMS Topology Generation

- Topology: include all the Tier 1 and Tier 2 sites in the US:
  - PerfSONAR: average throughput between sites
  - 10s - 100s Gbps typically



Data Distribution and Access Performance Improvements

- VIP distributed caching algorithm developed at Northeastern
  - Set of distributed and adaptive caching algorithms
  - Minimizes the total network cost (e.g., link delays)
  - Intelligent multipath routing and caching

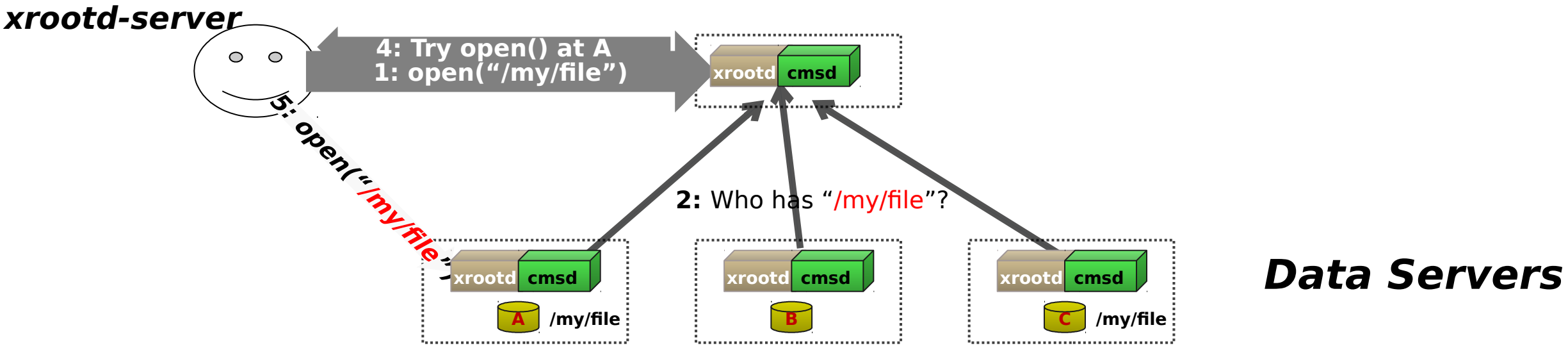
- Simulated over the derived CMS topology
  - Reduced total network cost by a 1000 times compared to stock routing and caching
  - Average data retrieval delays reduced by 50%

Integrating with current workflow

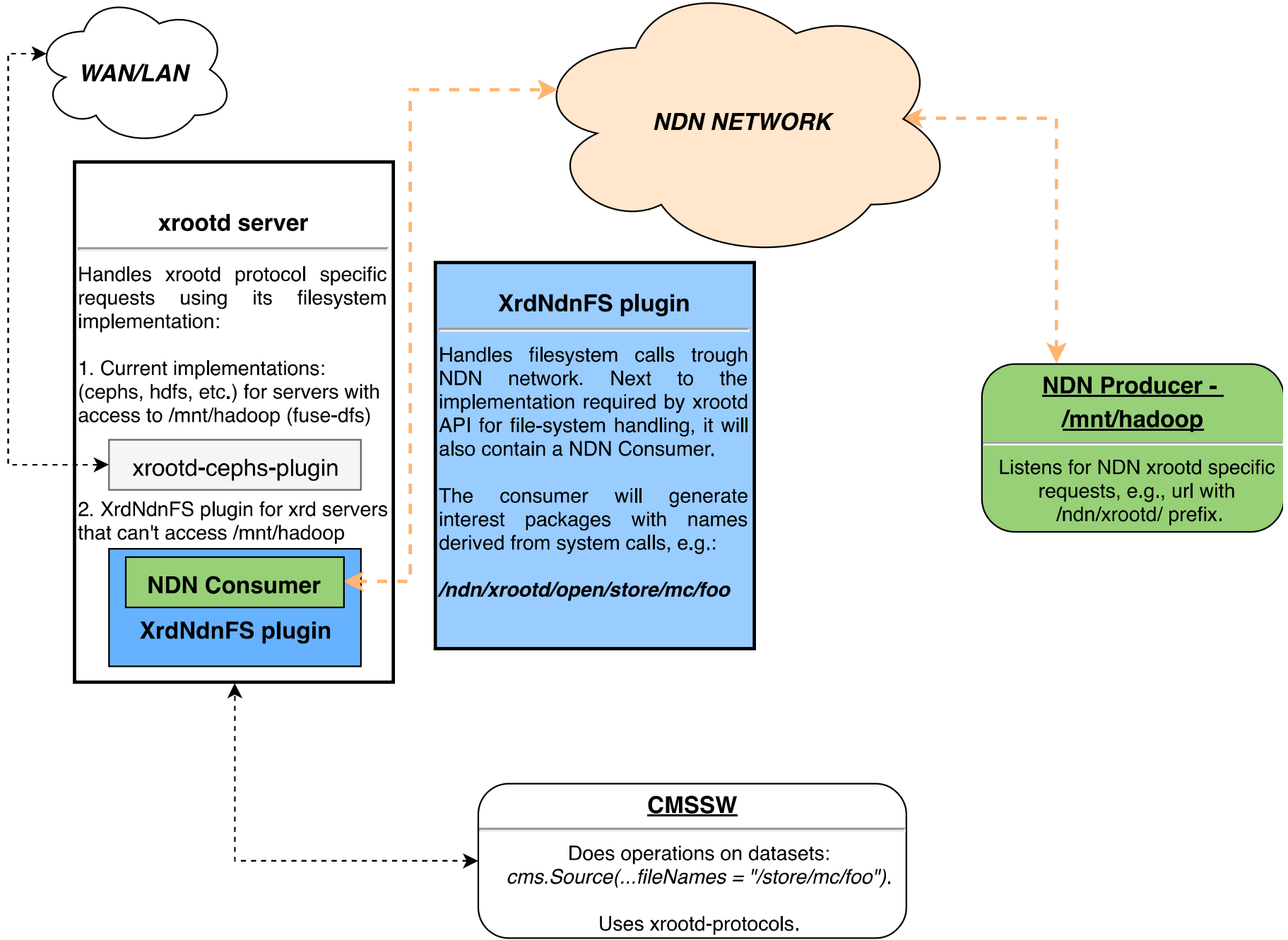
Integration with the mainstream data production and analysis tools of CMS

- Goals - Increased efficiency and reduced complexity for both applications and the network
- Create value for the HEP communities
- Integrate with xRootD, the de-facto data management software
- **First step** – an NDN based filesystem plugin for XRootD and a suitable NDN Producer

XrootD


xrootd-server
4: Try open() at A
1: open("/my/file")
xrootd
cmsd
5: open("/my/file")
2: Who has "/my/file"?
xrootd
cmsd
A
/my/file
xrootd
cmsd
B
xrootd
cmsd
C
/my/file
Data Servers

Architecture and flow diagram



The NDN Consumer for XRootD plugin

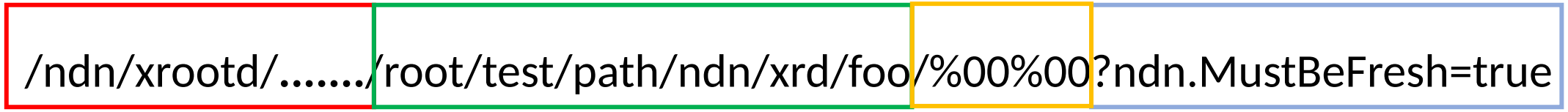
- Support for: **open**, **fstat**, **read** and **close** system calls

- Composes **Interests** for these system calls over NDN:

/ndn/xrootd/……..	/root/path/for/ndn/xrd/foo	?ndn.MustBeFresh=true
ndn prefix	*path to file of interest.*	*ndn interest specific info*

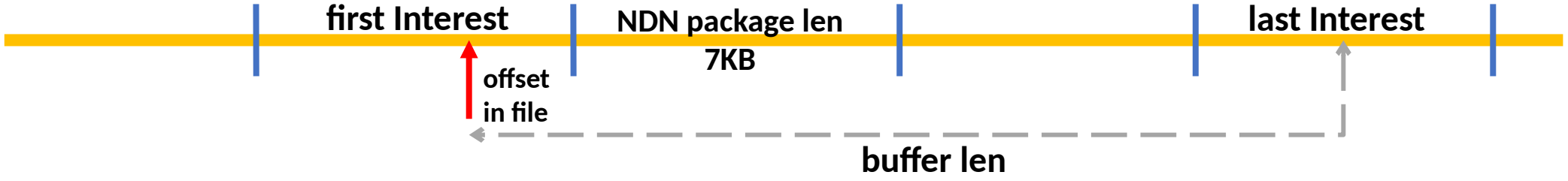
The NDN Consumer for XRootD plugin

ndn prefix *path to file of interest.* *ndn interest specific info*



ndn prefix *path to file of interest.* *seg. no* *ndn interest specific info*

- For read system call, it breaks down the request into segments.



- Handles: Interest validation, timeout and Nack with a maximum of 32 retries

XrdNdnFs xrootd plugin

- Packaged as a dynamic library (.so)
- Compiles the NDN consumer to handle the file system calls over NDN
- Handles: **open**, **fstat**, **read** and **close** file system calls

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An NDN Producer for XRootD plugin

- Registers prefixes to NFD

- Performs **open**, **fstat**, **read** and **close** system calls as required
  - No need to explicitly define operations

- Keeps track of opened files
- Sends data as strings and non-negative integers

/ndn/xrootd/.....	/root/path/for/ndn/xrd/foo/00/	?ndn.MustBeFresh=true&ndn.Nonce=825012545
ndn prefix	*path to file of interest.*	*ndn data specific info*

Demo

Using xrdcp tool to copy file:

```
[root@localhost ~]# xrdcp root://192.168.56.101:1094//root/test/path/for/ndn/xrd/test.txt .
[29B/29B][100%][==================================================][29B/s]
```

Consumer tracing:

```
180904 11:52:22 3997 root.4033:19@[::ffff:192.168.56.101] ofs_open: 0-600 fn=/root/test/path/for/ndn/xrd/test.txt
1536076342.630008 TRACE: [xrdndnconsumer] Sending open file interest: /ndn/xrootd/open/root/test/path/for/ndn/xrd/test.txt?ndn.MustBeFresh=true
1536076342.637558 TRACE: [xrdndnconsumer] Open file: /ndn/xrootd/open/root/test/path/for/ndn/xrd/test.txt?ndn.MustBeFresh=true&ndn.Nonce=825012545 with error code: 0
180904 11:52:22 3997 root.4033:19@[::ffff:192.168.56.101] ofs_fstat:  fn=/root/test/path/for/ndn/xrd/test.txt
1536076342.639412 TRACE: [xrdndnconsumer] Sending fstat interest: /ndn/xrootd/fstat/root/test/path/for/ndn/xrd/test.txt?ndn.MustBeFresh=true
1536076342.646256 TRACE: [xrdndnconsumer] Received data for fstat: /ndn/xrootd/fstat/root/test/path/for/ndn/xrd/test.txt?ndn.MustBeFresh=true&ndn.Nonce=2114664675
180904 11:52:22 3997 root.4033:19@[::ffff:192.168.56.101] ofs_read: 29@0 fn=/root/test/path/for/ndn/xrd/test.txt
1536076342.652151 TRACE: [xrdndnconsumer] Sending read file interest: /ndn/xrootd/read/root/test/path/for/ndn/xrd/test.txt/%00%00?ndn.MustBeFresh=true
1536076342.658508 TRACE: [xrdndnconsumer] Received data for read: /ndn/xrootd/read/root/test/path/for/ndn/xrd/test.txt/%00%00?ndn.MustBeFresh=true&ndn.Nonce=3348515939
180904 11:52:22 3997 root.4033:19@[::ffff:192.168.56.101] ofs_close: use=1 fn=/root/test/path/for/ndn/xrd/test.txt
1536076342.661787 TRACE: [xrdndnconsumer] Sending close file interest: /ndn/xrootd/close/root/test/path/for/ndn/xrd/test.txt?ndn.MustBeFresh=true
180904 11:52:22 3997 root.4033:19@[::ffff:192.168.56.101] ofs_close: use=0 fn=dummy
1536076342.670501 TRACE: [xrdndnconsumer] Close file: /ndn/xrootd/close/root/test/path/for/ndn/xrd/test.txt?ndn.MustBeFresh=true&ndn.Nonce=2386048754 with error code: 0
180904 11:52:22 3997 XrootdXeq: root.4033:19@[::ffff:192.168.56.101] disc 0:00:00
180904 11:52:22 3997 root.4033:19@[::ffff:192.168.56.101] XrdPoll: FD 19 detached from poller 0; num=0
180904 11:52:34 4002 cms_Finder: Waiting for cms path /tmp/.olb/olbd.admin
```

Demo – Producer tracing

```
[root@localhost ~]# source /opt/rh/devtoolset-7/enable
[root@localhost ~]# xrdndn-producer
1536076215.220043 TRACE: [xrdndnproducer] Alloc xrdndn::Producer
1536076215.220104 TRACE: [xrdndnproducer] Register prefixes.
1536076215.223160 INFO: [xrdndnproducer] Successfully registered prefix for: /ndn/xrootd/open
1536076215.223198 INFO: [xrdndnproducer] Successfully registered prefix for: /ndn/xrootd/close
1536076215.223214 INFO: [xrdndnproducer] Successfully registered prefix for: /ndn/xrootd/fstat
1536076215.223262 INFO: [xrdndnproducer] Successfully registered prefix for: /ndn/xrootd/read
1536076215.231777 INFO: [xrdndnproducer] Successfully registered prefix for: /ndn/xrootd
1536076342.632930 TRACE: [xrdndnproducer] onOpenInterest: /ndn/xrootd/open/root/test/path/for/ndn/xrd/test.txt?ndn.MustBeFresh=true&ndn.Nonce=825012545
1536076342.633349 INFO: [xrdndnproducer] Opened file: /root/test/path/for/ndn/xrd/test.txt
1536076342.633427 TRACE: [xrdndnproducer] Sending integer.
1536076342.635789 INFO: [xrdndnproducer] Sending: Name: /ndn/xrootd/open/root/test/path/for/ndn/xrd/test.txt/%FD%00%00%01e%A5H%E5i
MetaInfo: ContentType: 128
Content: (size: 1)
Signature: (type: SignatureSha256WithRsa, value_length: 256)

1536076342.643080 TRACE: [xrdndnproducer] onFstatInterest: /ndn/xrootd/fstat/root/test/path/for/ndn/xrd/test.txt?ndn.MustBeFresh=true&ndn.Nonce=2114664675
1536076342.643215 TRACE: [xrdndnproducer] Sending string.
1536076342.644782 INFO: [xrdndnproducer] Sending: Name: /ndn/xrootd/fstat/root/test/path/for/ndn/xrd/test.txt/%FD%00%00%01e%A5H%E5s
MetaInfo: ContentType: 0
Content: (size: 144)
Signature: (type: SignatureSha256WithRsa, value_length: 256)

1536076342.654514 TRACE: [xrdndnproducer] onReadInterest: /ndn/xrootd/read/root/test/path/for/ndn/xrd/test.txt/%00%00?ndn.MustBeFresh=true&ndn.Nonce=3348515939
1536076342.655736 TRACE: [xrdndnproducer] Sending string.
1536076342.657288 INFO: [xrdndnproducer] Sending: Name: /ndn/xrootd/read/root/test/path/for/ndn/xrd/test.txt/%00%00/%FD%00%00%01e%A5H%E5%7F
MetaInfo: ContentType: 0
Content: (size: 29)
Signature: (type: SignatureSha256WithRsa, value_length: 256)

1536076342.666803 TRACE: [xrdndnproducer] onCloseInterest: /ndn/xrootd/close/root/test/path/for/ndn/xrd/test.txt?ndn.MustBeFresh=true&ndn.Nonce=2386048754
1536076342.667471 TRACE: [xrdndnproducer] Sending integer.
1536076342.668575 INFO: [xrdndnproducer] Sending: Name: /ndn/xrootd/close/root/test/path/for/ndn/xrd/test.txt/%FD%00%00%01e%A5H%E5%8B
MetaInfo: ContentType: 128
Content: (size: 1)
Signature: (type: SignatureSha256WithRsa, value_length: 256)

1536076350.556002 TRACE: [xrdndnproducer] Dealloc xrdndn::Producer. Closing all files.
```

Other ongoing work

- Improve performance of producer/consumer
- Further integration with existing workflow and tools
- Modifying naming schemes for supporting next generation event forms such as NANO-AOD
- Adaptation of NDN to take advantage of SDN enabled infrastructures
- Tuning and optimizing NDN nodes for performance

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Thank You!