

Named Data Networking for Large-Scale Scientific Data and its Status on HEP

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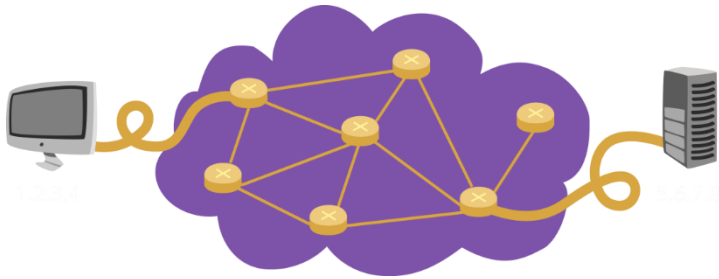
- **NDN Overview**
- **NDN Application SW for Large-scale Climate Data**
- **R&D Status on NDN Construction for HEP**
- **Summary**

Why Data-centric Networking ?

- The primary goal of communication (our concern) is data (content) itself, not connection to a host/server
- Current internet is a host (location)-centric communication model
- After identifying a host or server, identification of data (content) is always done later
- ICN architecture focus on data itself (object), not a host (method)
- Fewer steps are needed (i.e., put an unique name into data-centric networks and get a corresponding data, without identification of source/destination)
- Data-centric networking is more suitable in the data-driven world

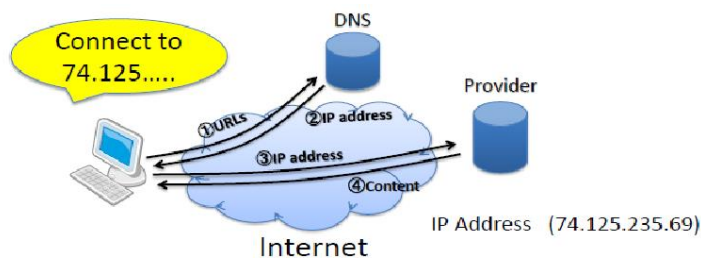
Current Internet vs NDN

- Named Data Networking (NDN) is one instance of **(ICN: Information Centric Networking)**



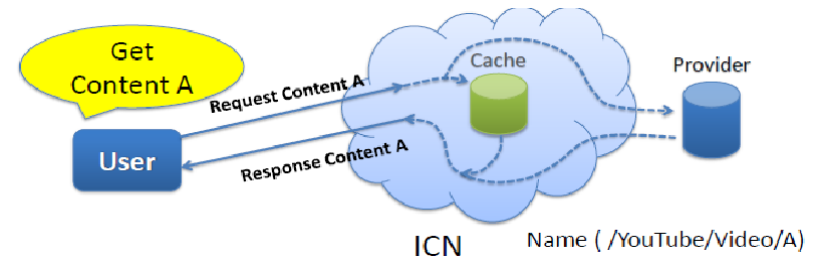
Internet Protocol

- Host centric comm. model
- Source/destination IP addresses needed
- Focus on delivering packets from source to destination
- Inefficiency in Security, mobility, QoS and scalability, etc.



Named Data Networking (NDN)

- Data centric comm. model
- Unique data names needed
- Focus on the **what (goal)** not the **where (host)**
- To reduce inefficiency due to host-centric networking in current Internet



NDN Philosophy & Feature

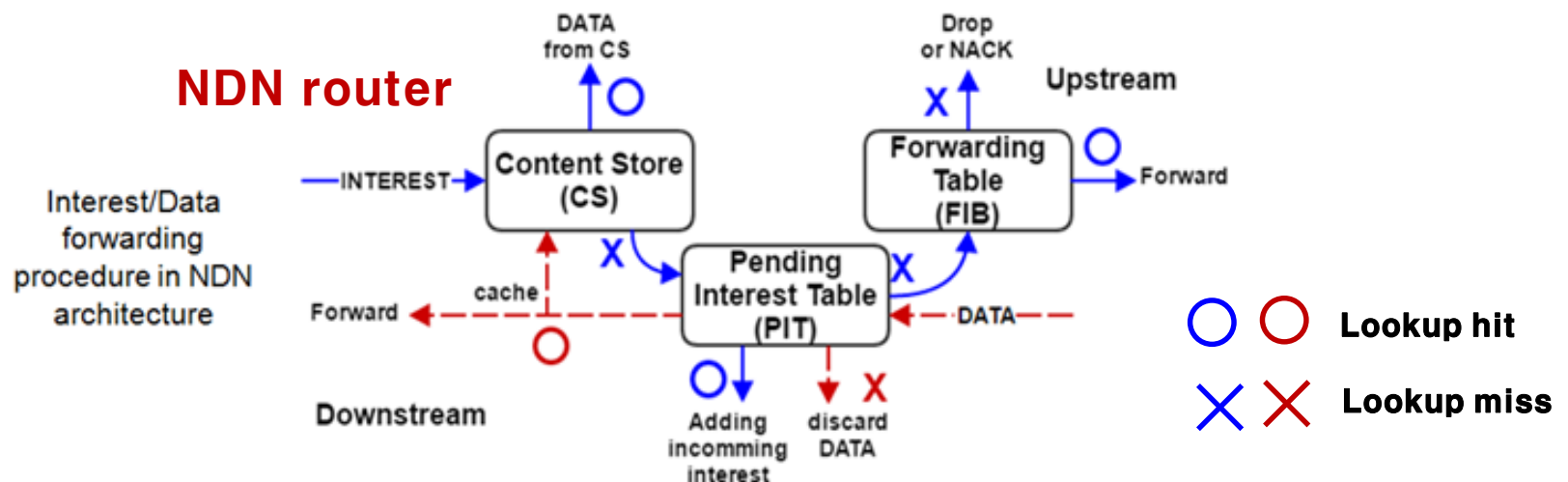
- **NDN philosophy**

- Focus on **Data** (i.e., content name), not **Host** (i.e., location: IP address)
- Redesign internet in a data-centric approach

- **NDN architecture features**

- Unique and hierarchical name
- Connectionless communication model
- Name-based forwarding
- Mobility and multicasting function are designed in architecture itself
- Securing content itself, not securing communication channel like IP
- Traffic reduction using In-network caching: Multiple duplicated data requests can be satisfied from nearby NDN router (cache: CS)

Using unique data name without source/destination IP addresses



Two Types of NDN Packets

Interest Packet

Content Name: Identifies the data I want to receive
Selector: identifier publisher, etc
Nonce

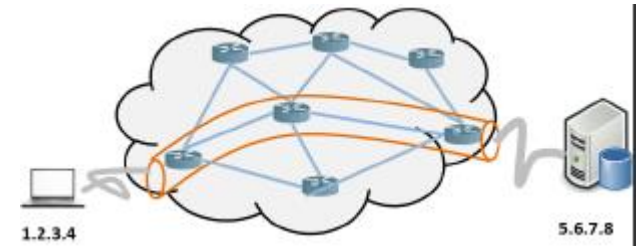
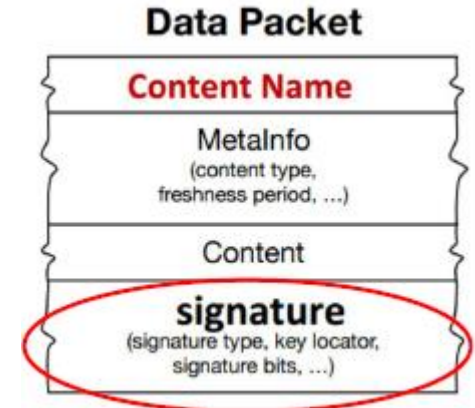
Data Packet

Content Name: Identifies the data in this packet
Signature: Required for all packets
Data

No source/destination addresses

NDN– Security

- Content-based Security in NDN
 - Security is built into content itself
 - Data packet has digital signature made by PKI (Public Key Infrastructure)
- signature securely binds together the tuple <name, data, publisher's key>
 - On the other hand, current IP networks secures the channel between two end points
- Verifying Data integrity and authentication

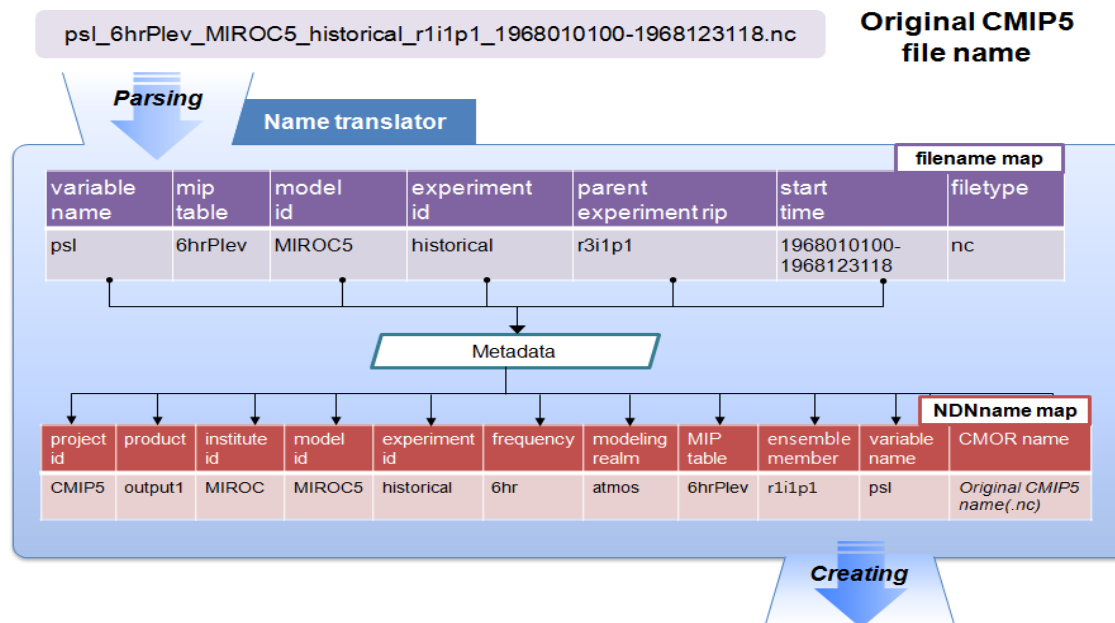
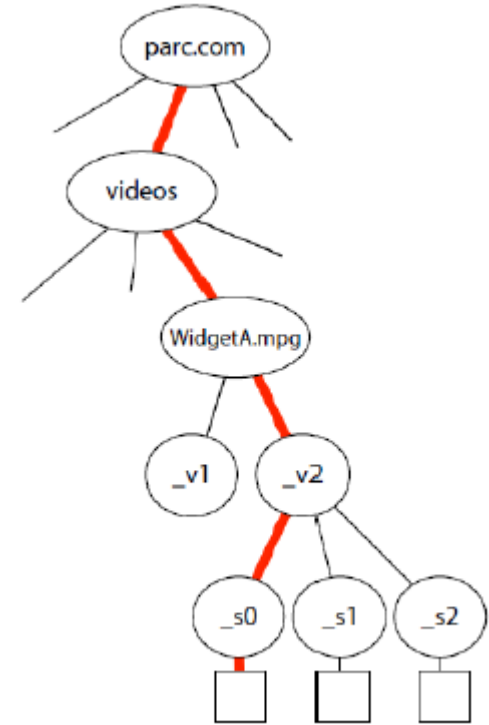


NDN – Naming

/parc.com /videos/widgetA.mpg /_v2/_s0

- Hierarchical
- Unique
- Human-readable

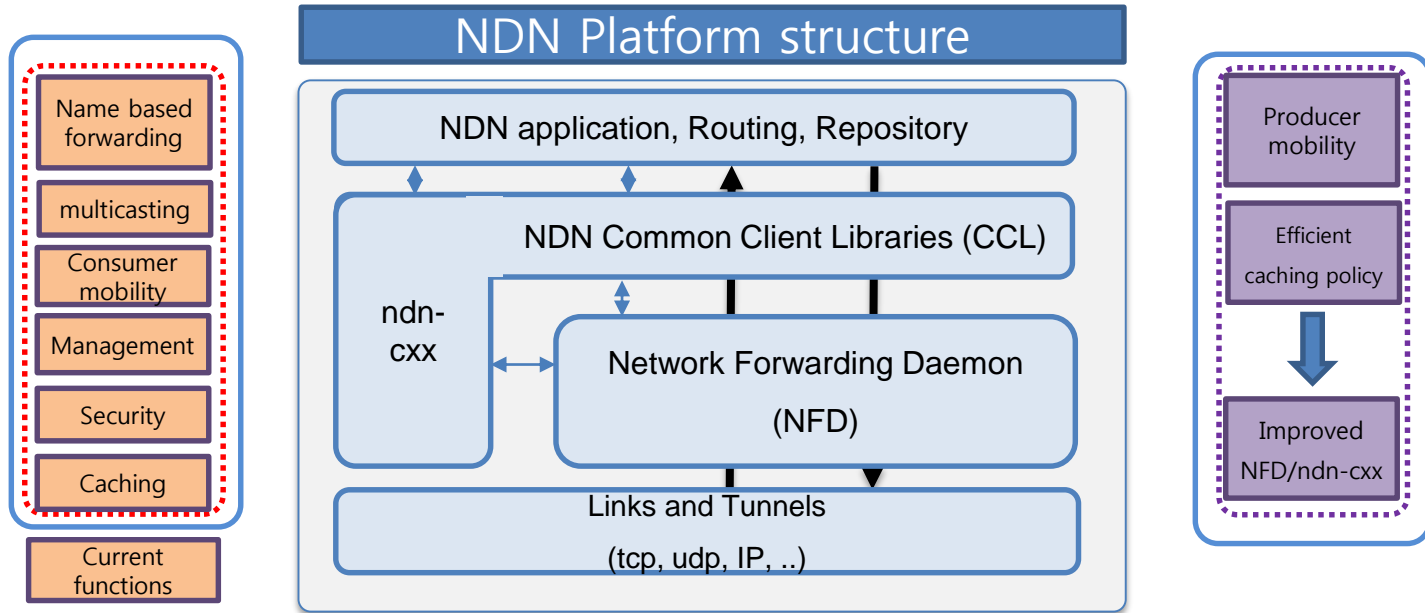
Naming scheme is the most important piece of NDN architecture and still under research



Converted NDN name

/CMIP5/output/MIROC/MIROC5/historical/6hr/atmos/6hrPlev/r1i1p1/psl/CMOR_name.nc

NDN Platform



NDN Platform ver. 0.1.0~0.5.1 (open source, Mar. 2017)

NDN Platform ver. 0.5.1

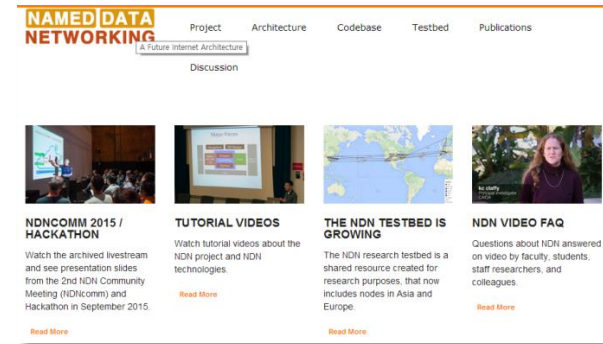
- ✓ **NDN-cxx v0.5.1** – Software router and C library implementation (Released mar. 2017)
- ✓ **NFD v0.5.1** – NDN Forwarder Daemon
- ✓ **NDN common client Libraries with TLV support**
 - Python – [PyNDN](#) – now fully implemented in Python, with a preliminary feature set.
 - Javascript – [NDN-JS](#) – with TLV support by default and user-selectable ndnb support.
 - C++ – [NDN-CPP](#) – with TLV support by default and user-selectable ndnb support.
- ✓ **NDN repository, NLSR, etc**

CCN Platform

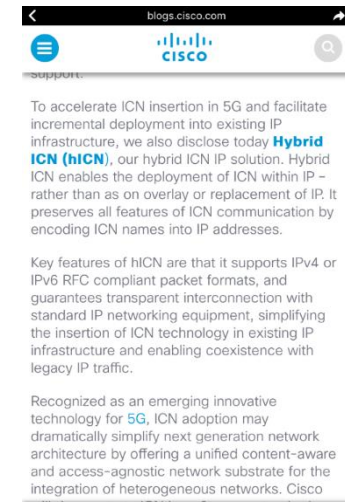
- **Developed by PARC over the past nine years**
- **CCNx ver. 1.0**

ICN (NDN) Application Area

- Content Delivery Applications (Streaming video, etc)
- IoT
- Healthcare
- Building management system
- Multiplayer online game
- **Large-scale scientific data**
 - Climate science data
 - HEP data
 - LIGO data
- **5G**
 - Cisco reported important steps toward adoption of CCN into 5G (Feb. 2017)
 - Hybrid CCN and its applications/solutions



NDN webpage: <http://named-data.net/>



NDN Overview

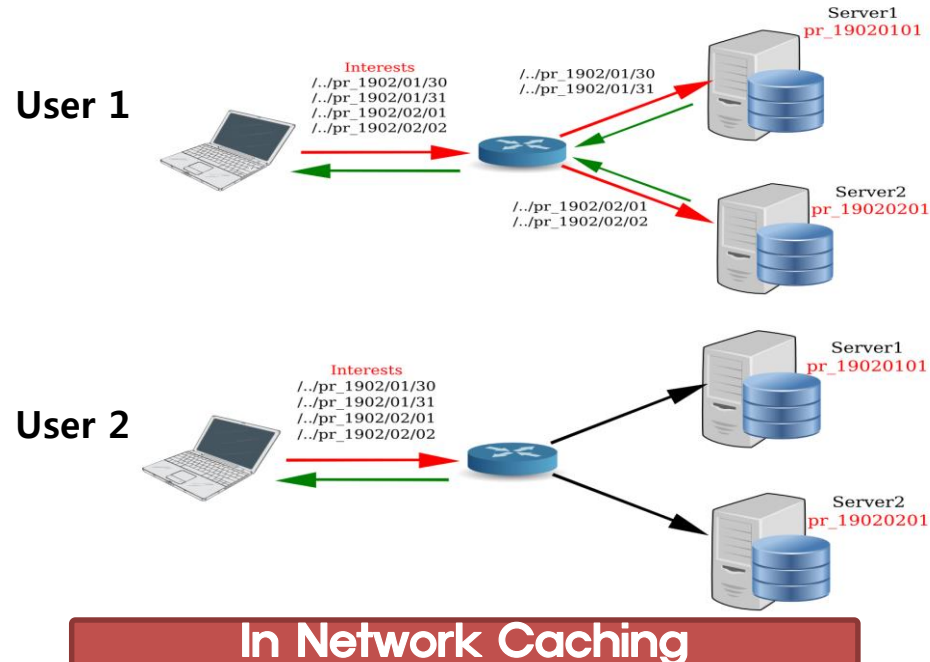
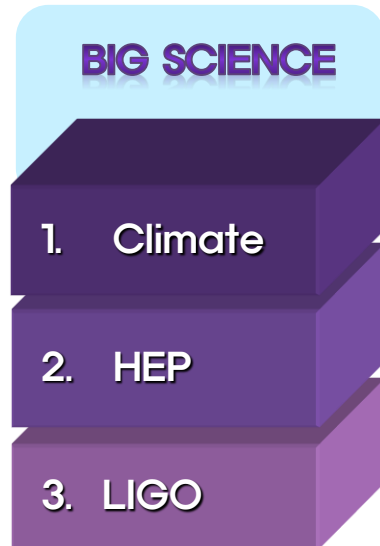
NDN Application SW for Large-scale Climate Data

R&D Status on NDN Construction for HEP

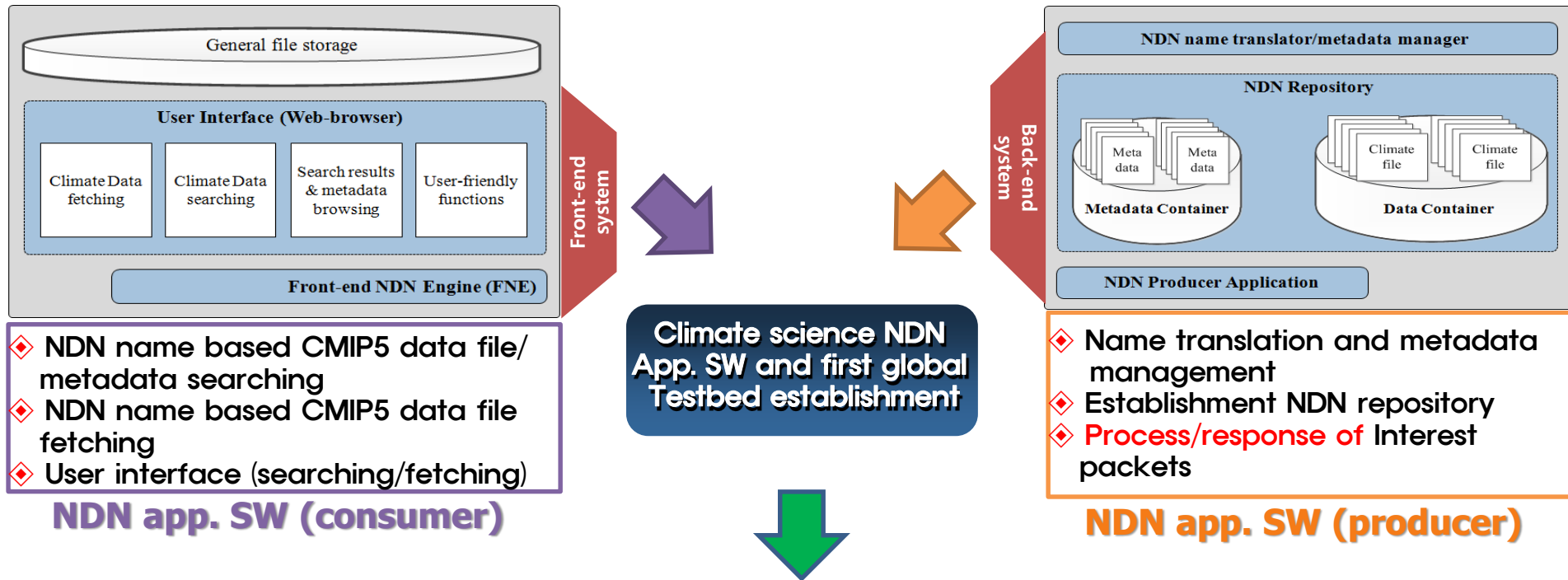
Summary

Why NDN for Large-scale Scientific Data

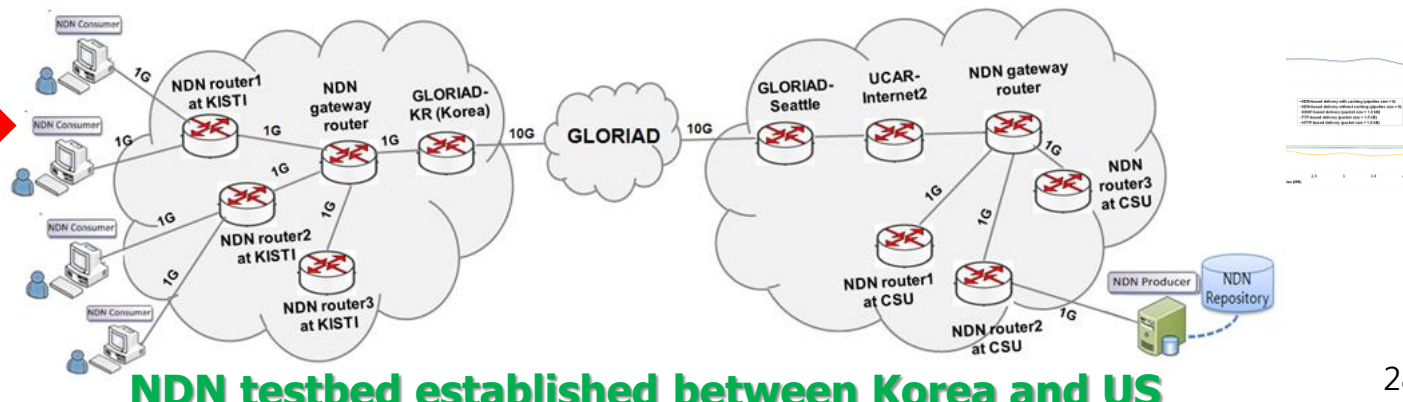
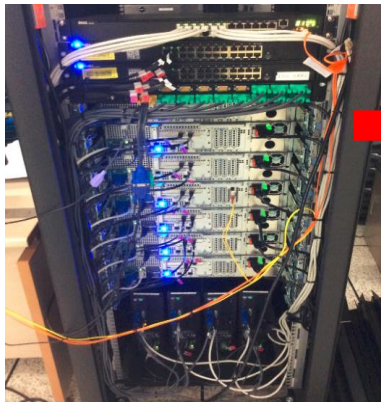
- ESGF (P2P file fetching system): **long latency/corrupted data** occur from globally distributed data centers
- Climate data file searching, fetching, management and security **based on data-centric networking**
- **Location independent climate data fetching**
- Remove redundant traffic using symmetrical forwarding /in network caching and reduce total amount of traffic in whole network



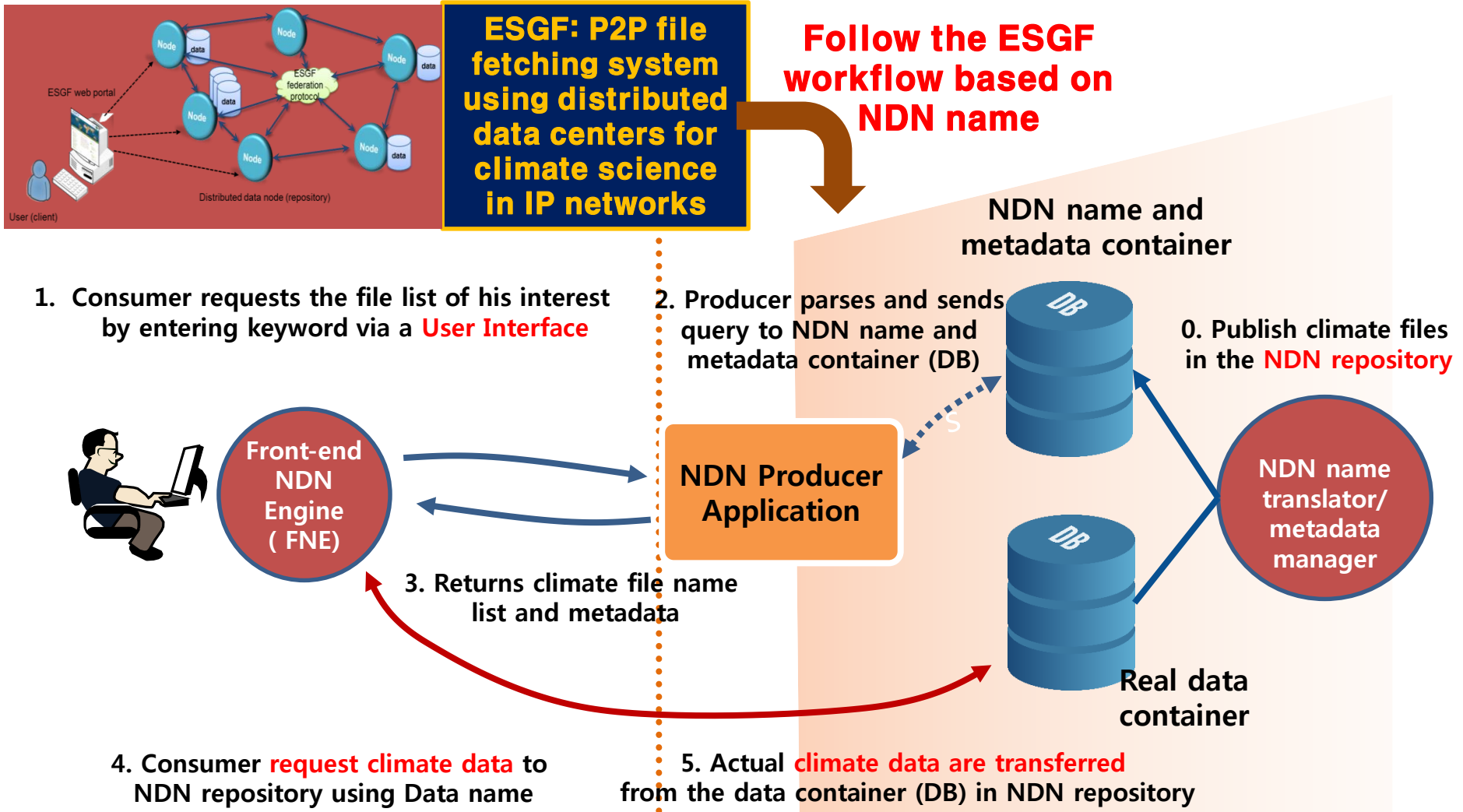
NDN Application SW for Climate Science



- Using Korea-US global NDN testbed, climate data file fetching experiment: justification of using NDN for large-scale scientific data
- The leading-edge technology on ICN app. SW for Scientific data
 - H. Lim, A. Ni, D. Kim, Y. Ko, S. Susmit, and C. Papadoplous, "Named Data Networking for Big Science: Lessons Learned from Establishing a Testbed", completed 2nd revision in *Computer Communications*, Jan. 2017.



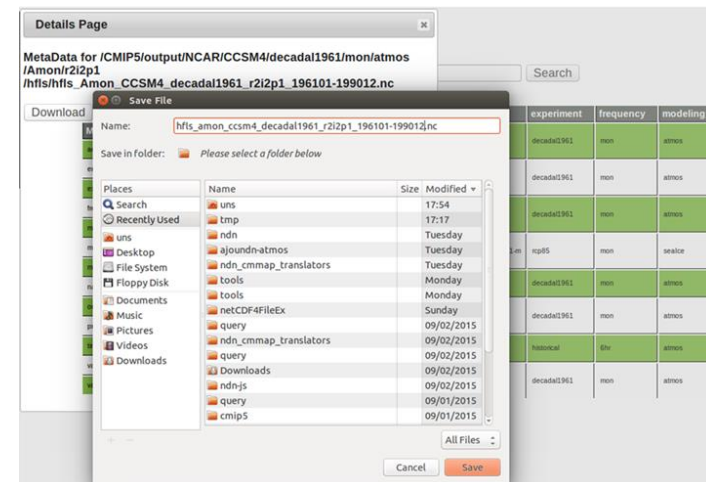
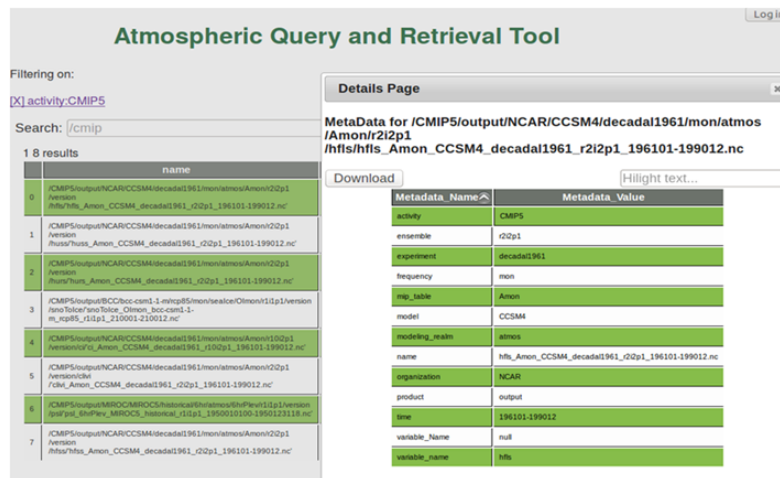
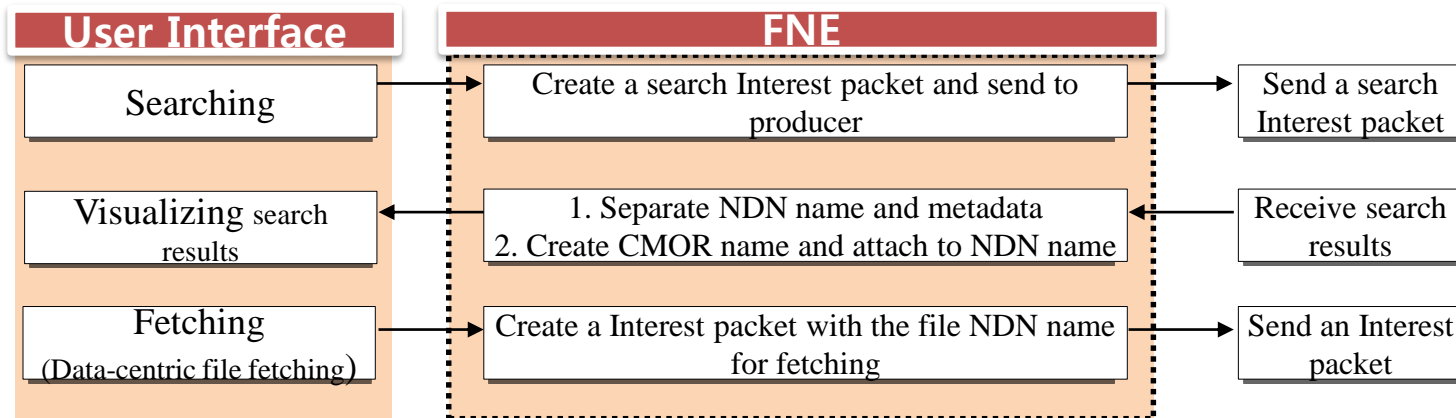
NDN based Climate Science Application Workflow



<Climate data file searching and fetching workflow using NDN names>

UI & Front-end NDN Engine (FNE) in Front-end System

- Using it, a consumer **search potential climate data files** (CMIP5 files)
- A consumer **fetches the desired file** with a target data name from the NDN network.



Screenshots of user interfaces; a) climate data (CMIP5) file searching and metadata browsing; b) climate data (CMIP5) file fetching

Components in Back-end System

● Name translator

- ✓ To convert original climate data file flat name to a hierarchical NDN name format (using one of DRS rules)

● Metadata manager

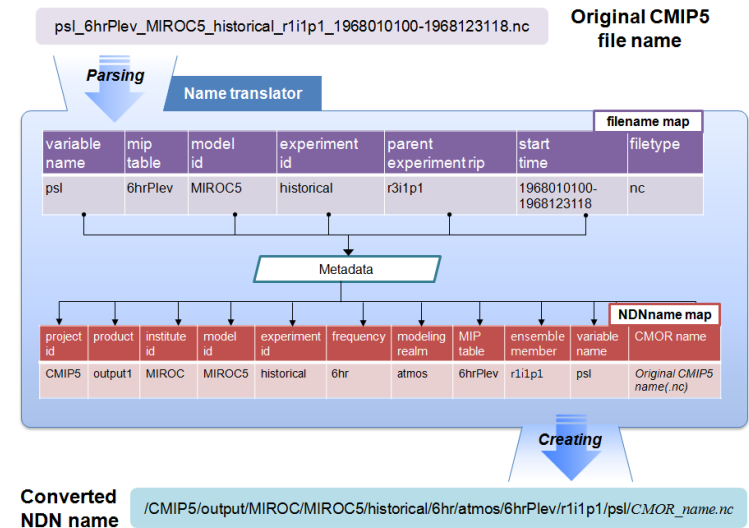
- ✓ To extract the metadata sets from each climate data file and manages them
- ✓ To provide detailed information for climate data files to consumers

● NDN repository

- ✓ Data container to store CMIP5 files and to support data fetching
- ✓ Name/metadata container to store converted NDN names and their metadata sets separately

● NDN producer application

- ✓ For an search Interest packet, it finds the corresponding data name carried in the Interest packet from the name/metadata container.
- ✓ It sends the NDN names and their metadata sets to the requesting consumer.



⟨Name conversion procedure⟩

Name Conversion Rule

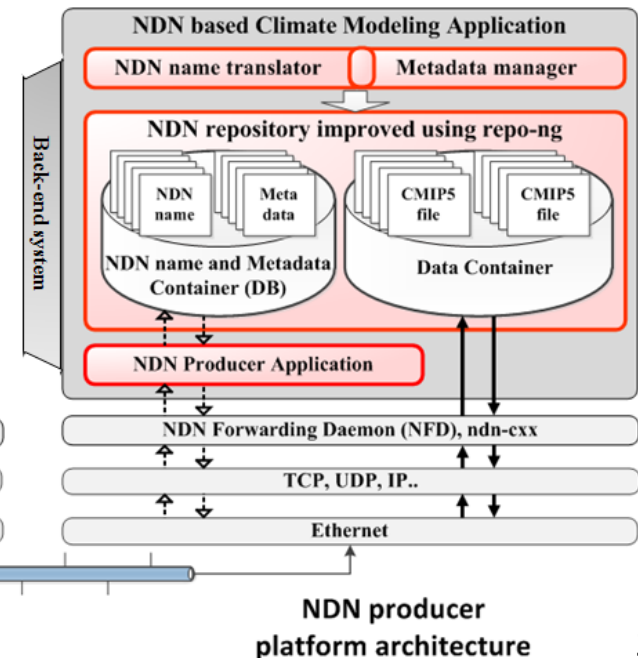
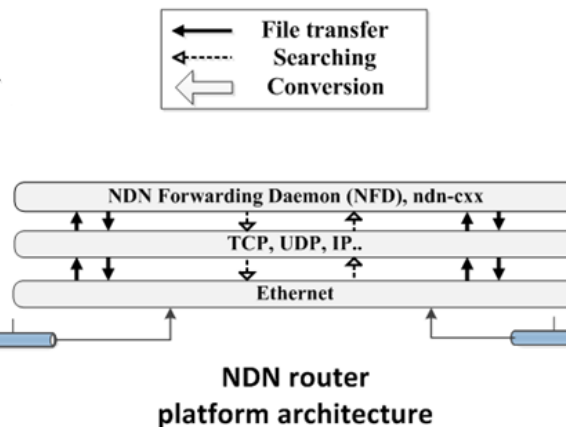
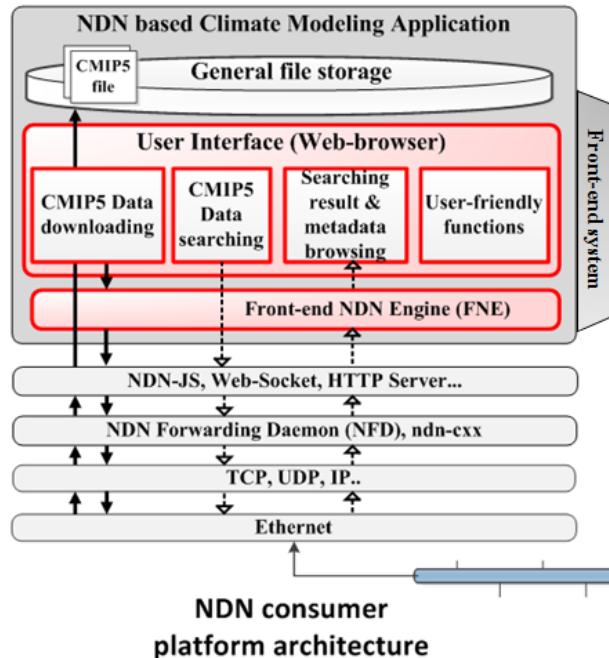
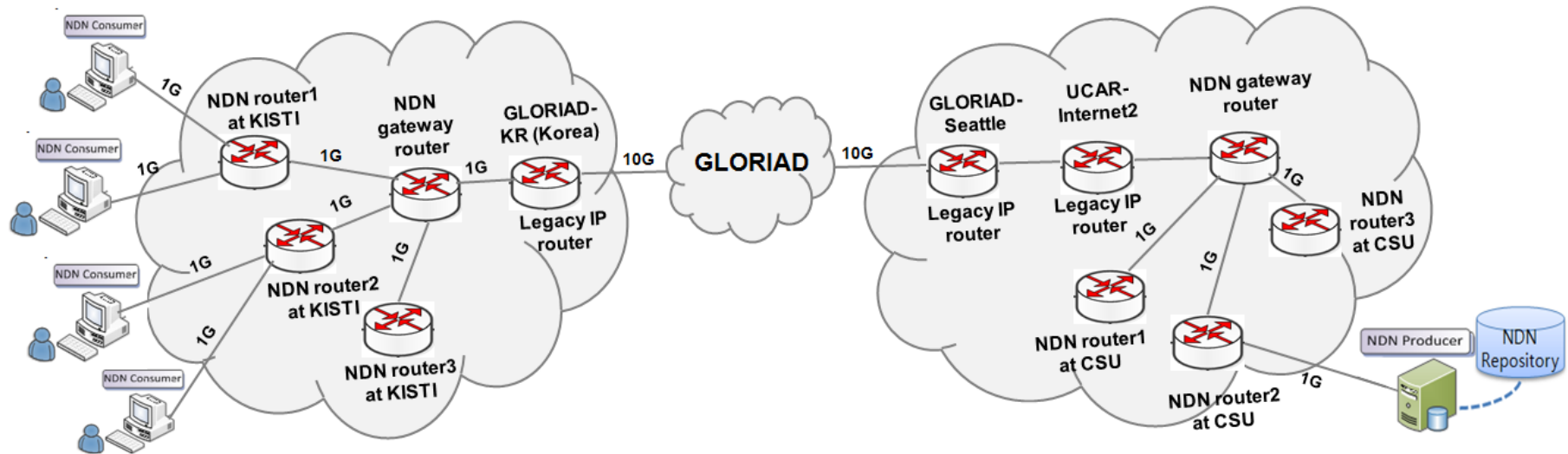
- Name conversion rule is based on *Data Reference Syntax (DRS)*
- Original climate file name (Flat names)

(a) Original CMIP5 data file name format (CMOR name)
<i><variable name>_<MIP table>_<model>_<experiment>_<ensemble member>[_<temporal subset>][_<geographical info>].nc</i>
<i>psl_6hrPlev_MIROC5_historical_r1i1p1_1950010100-1950123118.nc</i>

- NDN climate data name (Hierarchical names)

(b) Converted NDN name format
<i><activity>/<product>/<institute>/<model>/<experiment>/<frequency>/<modeling realm>/<MIP table>/<ensemble member>/<variable name>[/<CMOR name>.nc]</i>
<i>/CMIP5/output1/MIROC/MIROC5/historical/6hr/atmos/6hrPlev/r1i1p1/psl[/<CMOR name>.nc]</i>

NDN Testbed for climate science and its consumer/producer architecture



Climate Data Fetching Without TCP Tuning

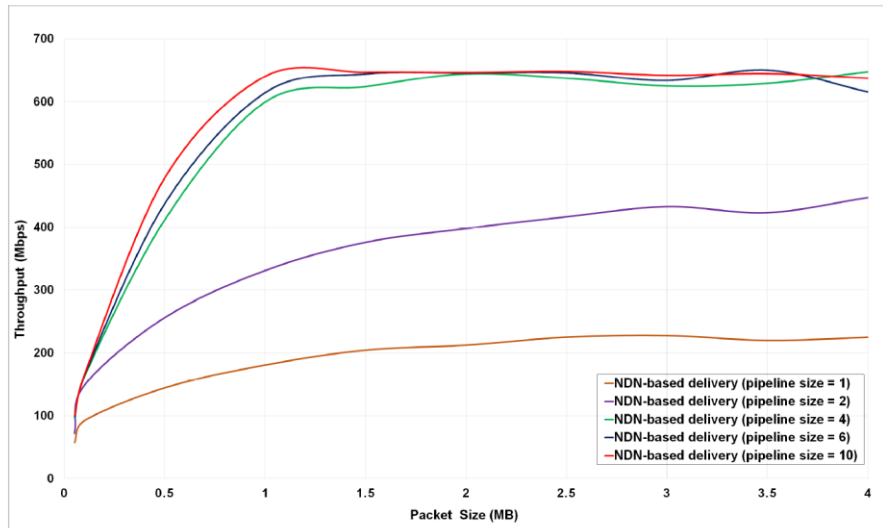


Figure 5: Throughput as a function of packet size for NDN-based delivery with different pipeline sizes.

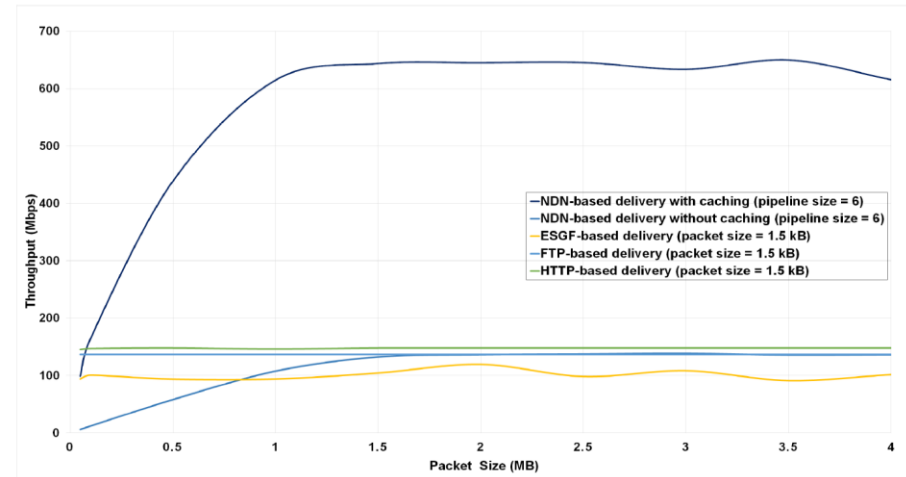


Figure 8: Throughput as a function of packet size for NDN-based delivery and classical delivery techniques (HTTP, FTP, and ESGF-based).

- For the climate modeling application, throughput no longer improved by a pipeline size greater than 6.
- For the NDN-based delivery with caching, intelligent data retrieval from the local distributed caches leveraged approximately 4.5-6.5 times the throughput improvement over the 1.5 MB packet size compared to conventional delivery techniques (FTP/HTTP/ESGF),

Climate Data Fetching with TCP Tuning

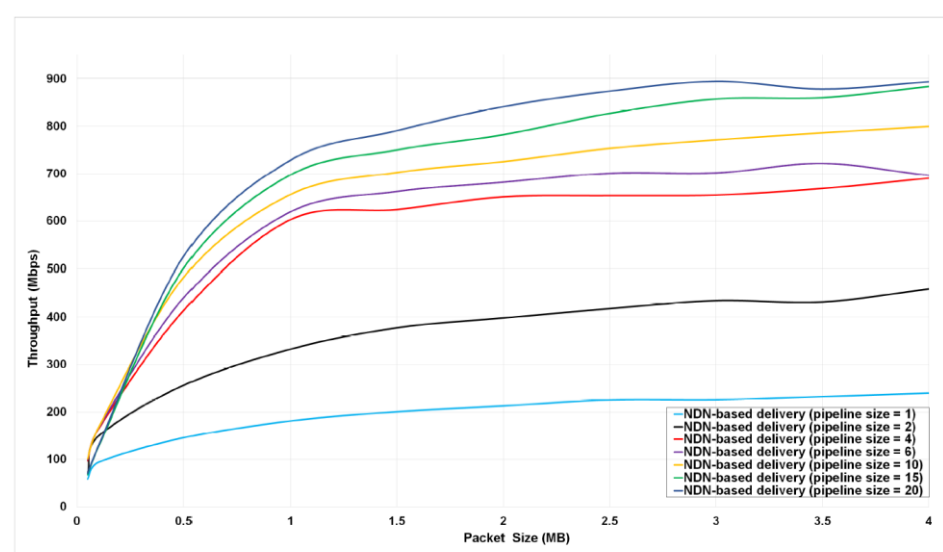


Figure 9: Throughput as a function of packet size for NDN-based delivery with different pipeline sizes (with TCP tuning).

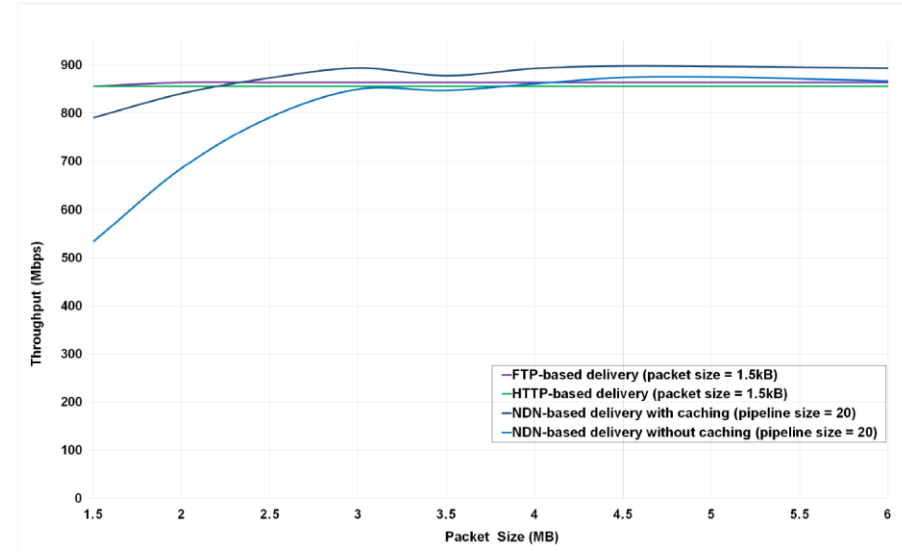


Figure 10: Throughput as a function of packet size for NDN-based delivery and HTTP/FTP-based deliveries (with TCP tuning).

- With TCP tuning, an improved end-to-end throughput could be achieved in the overlay-based NDN testbed including legacy IP routers.
- the throughput of NDN-based delivery saturated at 900 Mbps over a pipeline size of 20 and a packet size of 3 MB
- For the NDN-based delivery with caching, intelligent data retrieval from the local distributed caches leveraged approximately 50 Mbps the throughput improvement over the 3 MB packet size compared to classical delivery techniques (FTP/HTTP)

NDN Benefits for Large-scale Scientific Data

- **Named data-driven**
 - Just data name is needed without location information
- **In network caching**
 - High caching ratio of static scientific data improves throughput and user latency
- **Security**
 - Secure scientific data itself by signing of publisher
- **Symmetrical forwarding**
 - Allows multicasting and remove redundant traffic in whole networks
- **No perceptible transport**
 - Control of interest rate between NDN routers
 - no end-to-end transport control
- **Mobility in architecture itself**

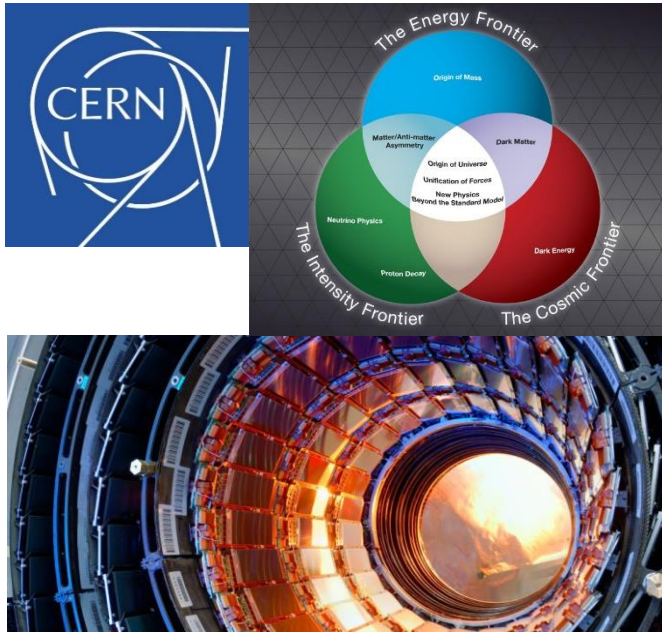
NDN Overview

NDN Application SW for Large-scale Climate Data

R&D Status on NDN Construction for HEP

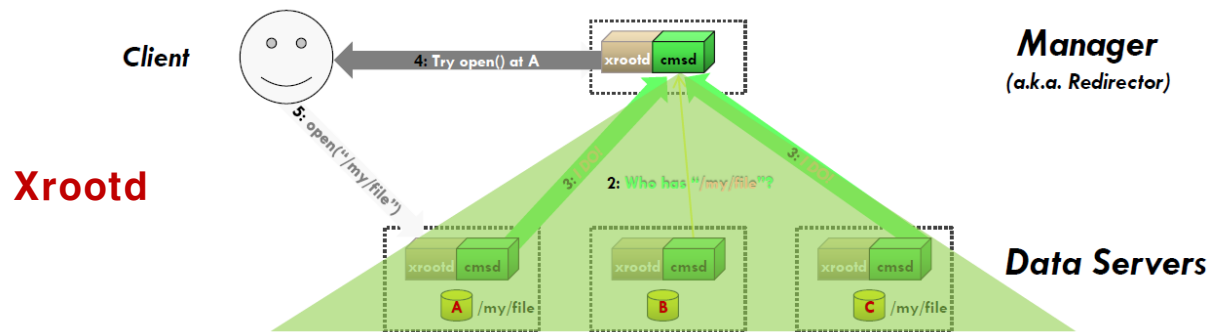
Summary

Challenges in High Energy Physics

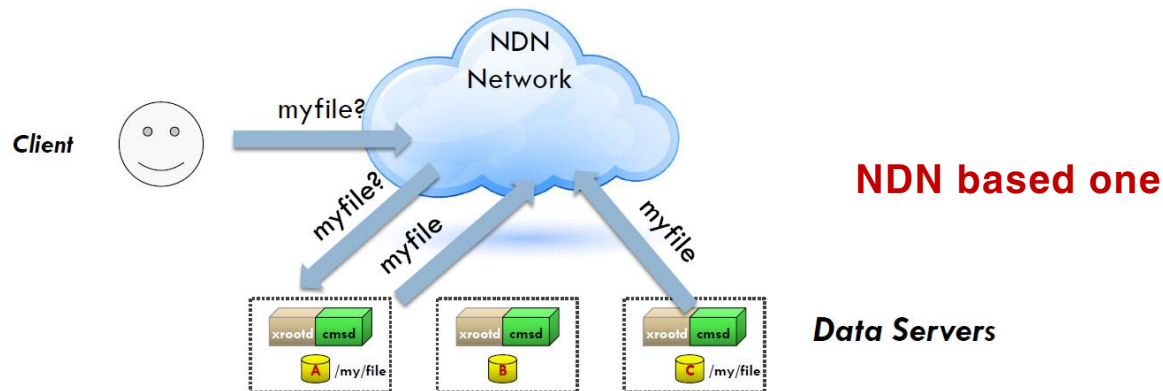


- The data-intensive science and LHC community are going to face major issues in nearest future.
- By 2018 LHC already handles the ~ 1 Exabyte of scientific data and will handle more by 2023.
- Data complexity is increasing together with the data size.
- LHC is a network of nearly 500 sites that responsible for different tiers in scientific data production.

Xrootd and NDN-based One



- Manager (Redirector) - discovers the actual location of the data and redirects the client to the appropriate site.
- Single point of failure of the manager

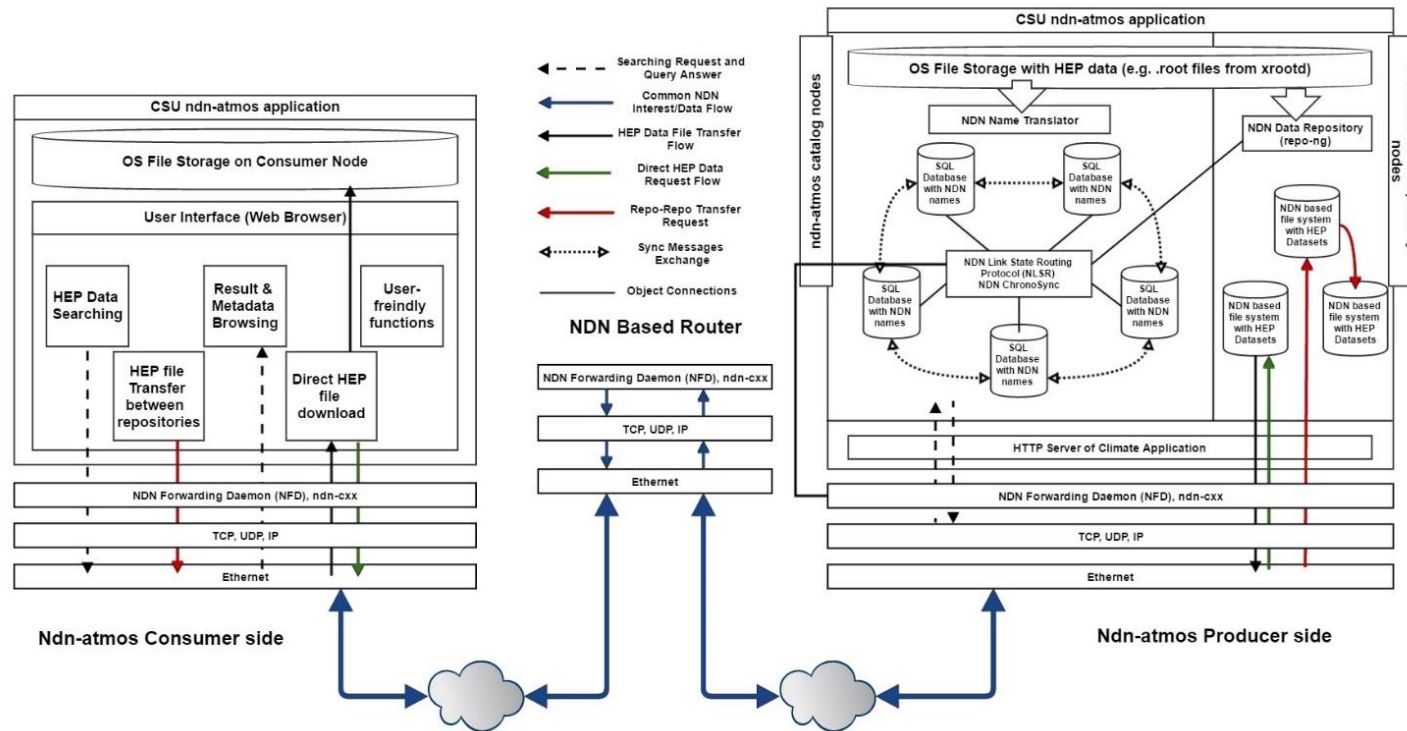


- NDN enables users to do location-independent data searching/fetching through data-centric communication model, not host-centric one
- By transferring the duties of manager to NDN network, it also reduce the number of steps that system will need eventually serve the data.
- By combining the two steps it increase overall performance and robustness of the system

Activities on NDN Construction for HEP

- KISTI attempts to make the NDN-based application SW for dark matter research data in particle physics
- CSU is working on their client side improvements like fixing metadata. CSU is targeting to make their application and NDN data repository more integrated into OS.
- Northeastern university starts to leading the SANDIE (HEP/LHC) project together with Caltech and CSU.
- Fermi lab is expected to collaborate with the SANDIE project

NDN-based HEP Application Structure by CSU



- **NDN Name Translator:** for converting various file names into NDN naming form. After translation it is stored at one of the catalogs nodes and then shared with other nodes.
- **NDN Data Repository (repo-ng):** NDN-based file system for storing actual data files.
- **NDN-based HEP Catalog:** the actual system that enable users to search and discover scientific data names (name translator and SQL database with NDN names)
- **UI:** user interface with such features like file searching, selecting, and fetching.
- **NDN Link State Routing (NLSR):** intra-domain routing protocol for NDN
- **NDN ChronoSync:** synchronization protocol for the data names list in all catalogs of one network.
- **Repo-Repo Transfer Request:** for transferring data file between two different data repositories in time when needed. It is utilized through application UI.

HEP Data Name Translation in NDN-based HEP Application

To translate HEP data into database, chain of directories was created inside the file system based on the full name of HEP file.

Full name of HEP file:

/RunIISpring15DR74/LQLQToTopMu_M-900_TuneCUETP8M1_13TeV_pythia8/AODSIM/Asympt25ns_MCRUN2_74_V9-v2/60000/A8710B21-6A09-E511-8F86-02163E012AA9.root

Its representation in file system:

```
/home
/home/hep_data
/home/hep_data/mc/
/home/hep_data/mc/RunIISpring15DR74
/home/hep_data/mc/RunIISpring15DR74/LQLQToTopMu_M-900_TuneCUETP8M1_13TeV_pythia8
.....
Etc.
```

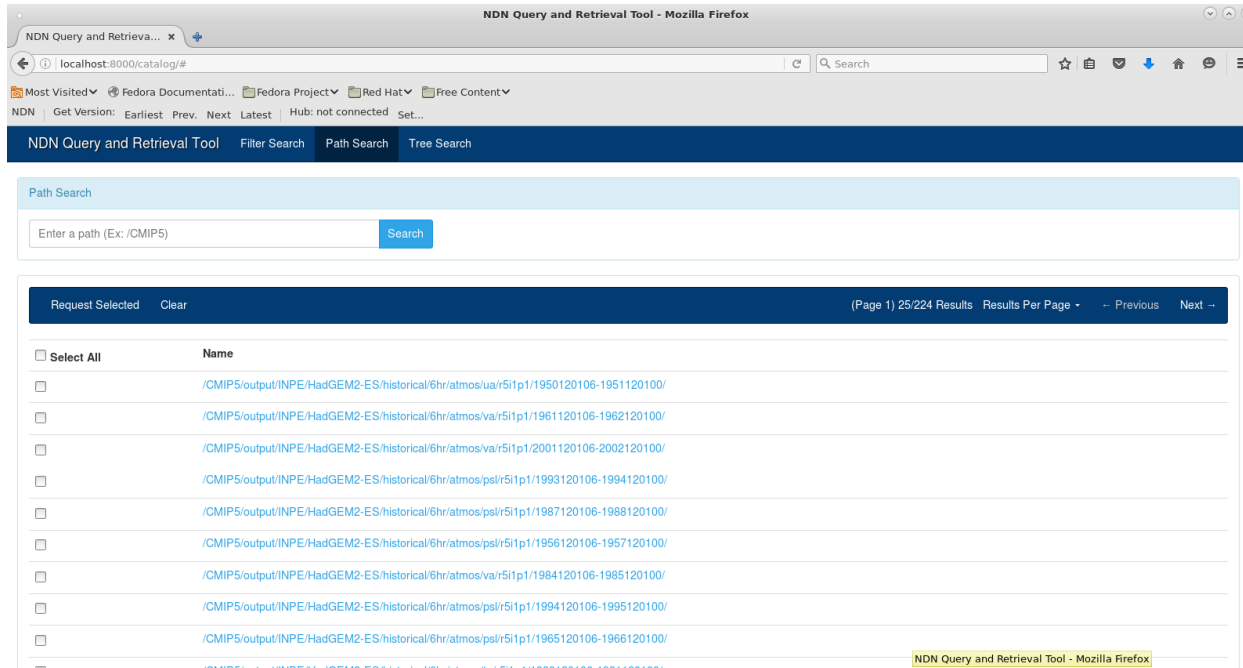
The ‘*mc*’ inside path is an important part of translation procedure. It’s playing the role of trigger when translator read the path to the actual HEP data file.

/home/hep_data/mc/RunIISpring15DR74/LQLQToTopMu_M-900_TuneCUETP8M1_13TeV_pythia8/AODSIM/Asympt25ns_MCRUN2_74_V9-v2/60000/A8710B21-6A09-E511-8F86-02163E012AA9.root

All information before ‘mc’ will be removed with ‘mc’ . The rest part will be utilized by translator and will be added to the database.

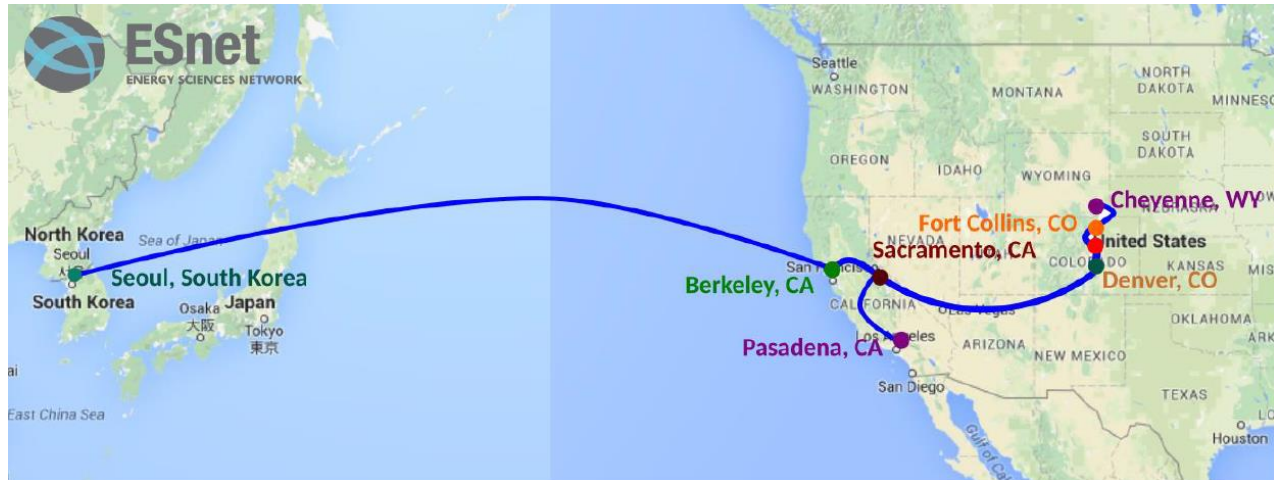
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UI in NDN-based HEP Application

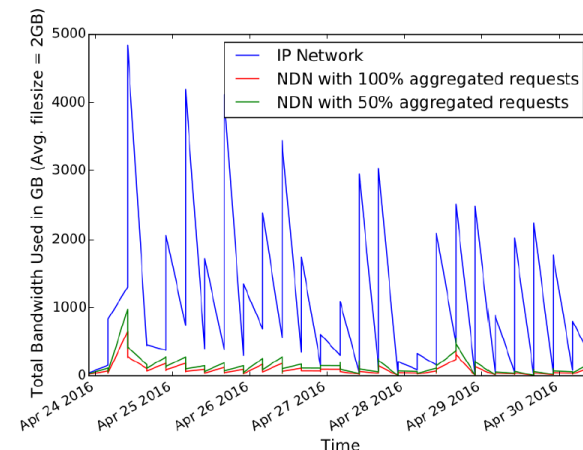


- NDN-based HEP application by CSU currently contain HEP translation tool and publish HEP files with the ability.
- HEP share the same data discovery and retrieval method as climate data, but HEP translator itself requires additional minor configuration to be used.
- HEP use the same User Interface for climate data, it uses xrootd filenames to translate them into NDN name

Global NDN Testbed Established by KISTI and CSU for Large-scale Scientific Data

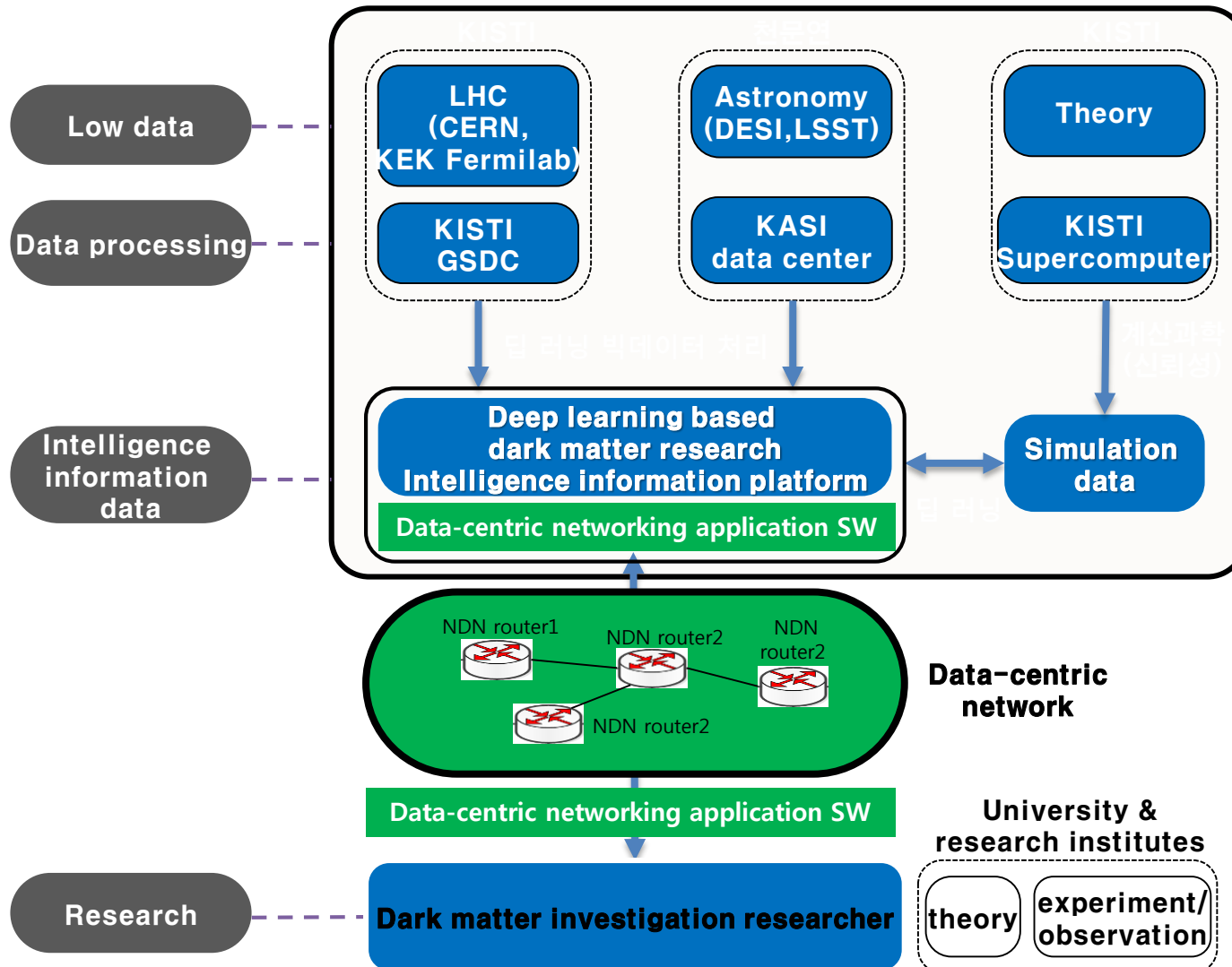


- 10G testbed (courtesy of ESnet, UCAR and CSU, and KISTI)
- Currently ~50TB of climate data, ~20TB of HEP data
- Bandwidth peaks 5000GB/10minutes (64Gbps)
- With 100% aggregation bandwidth drops to 8.2Gbps
- With 50 % aggregation bandwidth drops to 13.2Gbps



Bandwidth Reduction with NDN

R&D Project Plan on Data-centric Networking SW for Dark Matter Research Efficiency by KISTI



- Creative Association Project (CAP)
- KISTI & KASI & 10 universities
- KISTI: R&D on deep learning SW algorithm & data centric networking SW
- Planned to submit a proposal to NST (Mar. 2018)

SANDIE Project



**Software Defined Network-Assisted
Named Data Network for Data
Intensive Experiments (SANDIE)**

**is a Data-Intensive Science project for high
energy physics that combine NDN and SDN**

**Project initiated by: Northeastern Univ. ,
Caltech and Colorado State Univ.**

SANDIE aims to do

- **Lay groundwork for NDN-based data distribution and access system for data-intensive science fields.**
- **Benefits data-intensive science communities from lowered cost, location independent data access using data-centric networking**
- **Engages next generation of scientists in emerging concepts of future Internet architecture for data-intensive applications**
- **Advance, extend and test the NDN paradigm to encompass most of data-intensive science applications**

Summary

- **NDN Overview**

- One instance of ICN that is redesigned in a clean-slate approach (Interest/Data packet)
- Focus on WHAT (content data) not WHERE (host)
- Caching, security for data, mobility, and multicasting in architecture itself
- NDN Platform (ver ~0.5): NDN-cxx, NFD, Node.js, NDN-ccl, repo-ng, nlsr
- IoT, healthcare, scientific data app., 5G (Cisco reported its adoption, Feb. 2017)

- **NDN application SW for large-scale climate data**

- A differentiated NDN app. SW for climate science (Front-end system/back-end system) by KISTI
- Establishment of first intercontinental NDN testbed between US and Korea using it
- Leading edge technology on data-centric networking based large-scale climate data searching/fetching

- **R&D status on NDN construction for HEP**

- KISTI is are moving to make an NDN app. SW for HEP dark matter data
- CSU is working on their client side improvements like fixing metadata in ndn-atmos. They are also targeting to make their application to cover NDN-based climate and HEP data searching/fetching simultaneously.
- Northeastern univ. start to leading a SANDIE (HEP/LHC) project together with Caltech and CSU.
- SANDIE is a Data-Intensive Science project for high energy physics that combine NDN and SDN.