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A Named Data Networking Testbed with Global NDN Connection

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ABSTRACT

Named Data Networking (NDN) is one of the powerfully evolving future internet architectures. In this paper installation, configuration and several tests are addressed to show how well and properly our NDN testbed have been prepared and established using NDN platform, in order to have interoperability with global NDN testbed. Global NDN testbed status with our NDN node participation was addressed. To verify one reachability on the NDN connection to global NDN testbed, a latency result is presented using NDN ping test.

Key Words : Named Data Networking (NDN), NDN testbed, future internet, global NDN connection, NDN ping test

Ⅰ. Introduction

Conventional networks are mostly based on IP architecture that has many limitations and disadvantages for the image of future networking. Current Internet is host-centric network and strongly depends from stable link with an end host. At the same time there are security problems in host-centric system that are not only in trust between two points, but also, any intervener that is able to connect to the link between them can easily get access to all information that is going through it. Any data is need to be retrieved directly from the source, that is strongly increase the load on link in certain direction and create congestion and packet losses. The user of conventional Internet is sticked to his location and any change of position from one place in the network to another will strongly affects on network and will make the source unreachable, before it will obtain a new address.

Named Data Networking (NDN), one of the future internet architectures, that is providing the view on how modern internet should be revolutionized. NDN realizes not a destination address but a content name, that is hierarchically structured and can be adapt to a preferable naming strategy[1]. These names are human readable and can solve the limitations of host-centric communication[5]. NDN goes away from host-centric network to data centric, where the origin of the content does not matter and data can be retrieved not only from its direct provider but also from intermediate nodes. Packet fetching from the intermediate nodes brings many advantages of improved latency and decrease packet loss for content data, because data packets can be recalled from the closest node, that still have it in its cache. NDN packet type is divided to interest packets which carries the information from the requester to the source, and data packets that are carrying demanded information to the consumer[11]. All packets that transferred through NDN are signed and this point significantly increase data protection in the web. At the same moment signing procedure in NDN is hierarchical and sequential, that makes

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security system very robust and efficient, resulting in enhanced trust to each piece of data that is send in the network[4].

Testbed establishment is an initial step to apply various applications on NDN. In this paper we will present some installation and configuration work and several tests on how well our NDN testbed were conducted and prepared for global NDN connection. Also we will provide a status information of our testbed in Global NDN network.

Ⅱ. Related Work

2.1 Global NDN Testbed

The NDN project have a global testbed with great number of nodes all over the world. It operates 26 nodes with 66 connection links. They are linked to each other on various NDN applications which are working with a variety of naming and forwarding strategies. Global NDN testbed is partially using TCP or UDP tunneling for packet forwarding, in order to incompatibility of basic forwarding operation in NDN with current IP networks.

For climate modeling application, Colorado State University (CSU) has implemented there own NDN testbed in US. Currently they are developing an NDN based user interface to search and download climate modeling data that is taken from the CMIP5 research project[12], that is containing a big amount of different climate data sets. Also, HEP community in US are about to develop an NDN testbed for their HEP research, and they have decided to use an hierarchical file name structure as an initial point of their research[8].

2.2 Domestic NDN testbed

A domestic NDN testbed node that has been established in global NDN testbed is Anyang University node. They established and configured their NDN node for its global NDN testbed operation. The NDN node at Anyang Univ. has the connection with 5 neighbor nodes including a node in KISTI NDN testbed. This node is distributing its site prefix into the global NDN testbed and represent its statistic information on the NDN map. By this time the NDN node machine have more then 70 entries in FIB. Most of them are main site prefixes in global testbed nodes, which are used to work with Name Data Link State Routing (NLSR) protocol[3].

Ⅲ. Established NDN testbed

We have established and configured our NDN testbed for climate modeling application (Figure 1). It has eleven nodes with 4 consumers, 6 routers and 1 producer that are linked with 10G connection for NDN operation. All nodes except consumers have 8 TB of disk space on each machine, also we are using Linux-core operation system on all this machines. On this nodes we have installed NDN SW platform ver. 0.3.3, including NDN Forwarding Daemon (NFD)[10], ndn-cxx library which is C++ library, Link State Routing Protocol (NLSR) ver. 0.2.1, and application tools (i.e., ndn-ping, ndn-peek and ndn-poke) for traffic reachability test.

Fig. 1. Established NDN testbed

3.1 Description of NFD and ndn-cxx structure

NFD is a main segment of NDN platform and has several components. NFD is targeted to forward and control all kind of NDN packets. NFD platform consist of Core, Tables, Faces, Forwarder, RIB manager and Management parts, and is directly connected with ndn-cxx library and ndn tools. Figure 2 represents connectivity between all components of NFD where forwarding section directly interacts with faces, tables and strategies

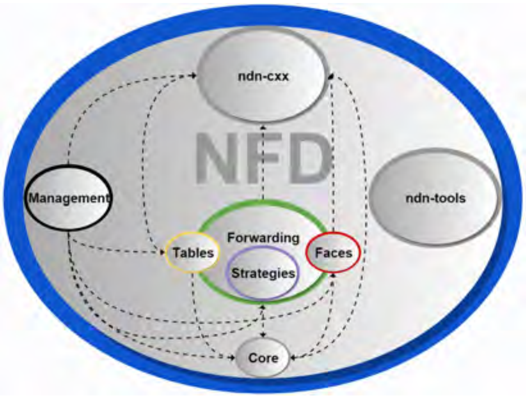

Fig. 2. NFD Components overview

which are the main part of forwarding section and provides various forwarding strategies in it. Faces are representations of transport layer in NDN, and Tables addresses to Forwarding Information Base (FIB), Content Store (CS) and Pending Interest Table (PIT) in NFD, there are also Management module. Management module is controlling the most part of NFD modules, it also include RIB management operations. The RIB may be updated by the different ways and different groups of users. RIB management module processing requests and generate constant forwarding table, synchronize it with more narrow NFD FIB. Forwarding in NFD supported by such common services like: Core module, ndn-tools and ndn-cxx. And ndn-cxx - it is C++ library that provides various basic functions and classes that are implemented in NDN and in NFD are playing the role of supplementary that support all core services.

3.2 Configuration and operation

Our testbed topology is shown in Fig. 3, producer 1 is answering on interest packets that are coming from the several consumer that are connected to different routers. So all local interest and data flows are circulating across the several routers between four consumer nodes and one producer node. All nodes, except producer 1 have FIB entries to forward to certain faces. We have used a short prefix name (i.e., /ndn/cmip5/kisti) and faces represent network interfaces in each node. That prefix and face binding helps to forward packets from one point to another.

We have configured our NLSR application. That work has been done in cooperation with Washington University of St. Louis (WUSTL), which is responsible for management and maintenance of the

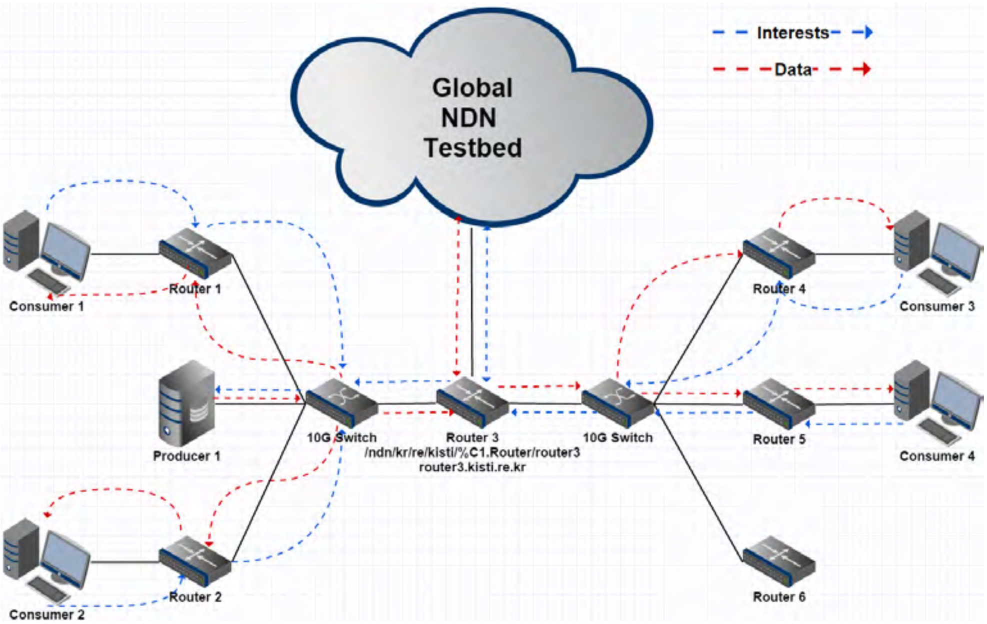

Fig. 3. KISTI NDN testbed with link toward global NDN testbed

global NDN network. Router 3 (R3) was chosen as KISTI representative node in global NDN. There are several steps to configure the router for this duty. The first one is a configuration process for the to join the global NDN testbed is made up of sequential network key generation, signing and shaping of routing protocol configuration file. Key signing process are divided to 4 steps: root key generation and self signing; site key generation and signing by the root key; operator key generation and signing by the site key; router key generation and signing by the operator key. The second step is the NLSR file configuration that consists of the router name assigning, adding of neighbor node information and prefix name specification. The NLSR is in charge of exchanging of name prefixes and synchronization of Routing Information Bases (RIBs) between all nodes in the global NDN testbed. Prefix names of the nodes in global NDN testbed can be defined based on domain names where they are included. For example, the KISTI domain name (i.e., kisti.re.kr) can be used to make a name prefix (i.e., /ndn/kr/re/kisti) so that it is uniquely distributed in the global NDN testbed.

Ⅳ. Experimental Results

4.1 Global NDN testbed map with our participation

Figure 4 represent global NDN map with all its participants and connection links between them. This

Fig. 4. Global NDN testbed map (focused on Asian Region)

snapshot shows Asian region of Global NDN testbed. KISTI testbed can be seen on it, with other neighbor nodes: Japan (Waseda), China (BUPT, PKU, Tongji) and Korea (Anyang). By exchanging information between these neighbor nodes NLSR gets and synchronizes FIB information about all other nodes in global NDN testbed. The numbers in fig. 4 (near each link that are connecting nodes) represent real-time bandwidth.

4.2 Global NDN testbed status

The status web page to identify NDN router functionality in the global NDN network is shown in Fig. 5, which is a table with all site prefixes that are distributed in it. In this table, distributed prefixes are shown in the rows and participants router names in the columns. Status of each prefix is represented in 4 colors; green shows that node have prefix names in its FIB entry, red shows that there is no FIB entry and yellow represents that FIB entry does not exist in this node's domain. The raw and column

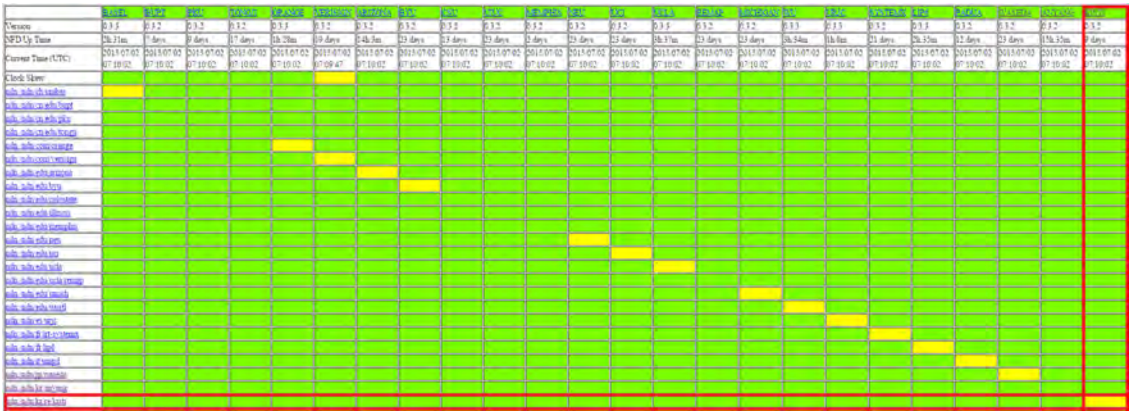

Fig. 5. Global NDN testbed status webpage

that are highlighted by the red boxes is our router (R3) status. The column with the red borders represents that site prefixes distributed from other domains are existing in our machine forwarding table. The raw with the red borders shows that our site prefix name is existing on all routers of global NDN network.

4.3 NFD Status

Figure 6 represents hypertext version of NDN testbed status information and consist of three sections: general NFD status, channels and faces. Also it provides full table of FIB and RIB entries and strategy types that are used, but only first three sections are presented in the figure 6. General NFD status section is divided into 14 columns that reflect the information about NFD: ID, version, up-time, all types of entries that were processed and in/out interest with data packets number. In figure 6 all three tables of the router (R3) contains entries, the same situation can be seen on interest and data flow columns. By the time of the snapshot, Router 3 have already processed several hundred thousands of data and interest packets. The Channels section shows all available packet transmission ways, like TCP, UDP or web sockets with standard ports that are used. The last section is Faces. It represents all faces that exist on the router and consists of local and remote faces with certain channel and destination information. Also it shows by face information about in/out interest and data packet number and their size in bytes.

4.4 Latency Result

Figures 7, 8 and 9 addresses the successful NDN ping test, that was achieved by the collaborative work with CSU. That was as a reachability test. The NDN ping application generates dummy interest packets, sends them to CSU domain, gets back data packets and represents each packet's round trip time information. Based on NDN ping application, we used a hierarchically structured prefix name (/cmip5/csu) and NDN TLV package type structure known as Interests and Data packets for its operation. As shown in Figure 7 we have established a connection between KISTI and Colorado State University domains. In this experiment CSU node operated as a producer and our domain as a consumer. The Consumer sends dummy interest packets and receives dummy data packet. All

Fig. 7. NDN ping test procedure between KISTI and CSU testbeds

NFD Status

General NFD status

NFD ID	Version	Start time	Current time	Uptime	NameTree Entries	FIB entries	PIT entries	Measurements entries	CS entries	In Interests	Out Interests	In Data	Out Data
/localhost/daemons/nfd/KEY/ksk-1434656508472/ID-CERT	0.3.2	2015-06-22 16:42:31	2015-07-06 02:32:44	13 days	1536	66	1296	0	65536	5084500	7393263	823898	737053

Channels

Channel URI
ws://[::]:9696
unix:///run/nfd.sock
udp6://[::]:6363
udp4://0.0.0.0:6363
tcp6://[::]:6363
tcp4://0.0.0.0:6363

Faces

Face ID	Remote URI	Local URI	Scope	Persistency	LinkType	Expires in	In Interests	In Data	In Bytes	Out Interests	Out Data	Out Bytes
1	internal://	internal://	local	persistent	point-to-point	Never	0	41854	0	77254	0	0
254	contentstore://	contentstore://	local	persistent	point-to-point	Never	0	0	0	0	0	0
255	null://	null://	local	persistent	point-to-point	Never	0	0	0	0	0	0
256	udp4://224.0.23.170:56363	udp4://203.253.235.168:56363	non-local	persistent	multi-access	Never	0	0	0	0	0	0
257	ether://[01:00:5e:00:17:aa]	dev://p5p2	non-local	persistent	multi-access	Never	0	0	0	0	0	0
258	fd://24	unix:///run/nfd.sock	local	on-demand	point-to-point	Never	38756	264474	238613272	264474	21994	137755694
266	fd://30	unix:///run/nfd.sock	local	on-demand	point-to-point	Never	1	0	441	0	1	828
267	fd://31	unix:///run/nfd.sock	local	on-demand	point-to-point	Never	1820920	103842	442434261	727737	501796	470972504
268	fd://32	unix:///run/nfd.sock	local	on-demand	point-to-point	Never	24749	0	1274022	0	7951	3391100
269	udp4://133.9.73.66:6363	udp4://0.0.0.0:6363	non-local	persistent	point-to-point	Never	0	0	0	1834924	0	159936080
2903	udp4://210.114.89.49:6363	udp4://0.0.0.0:6363	non-local	persistent	point-to-point	Never	281294	56742	84456220	580831	1	52892587
2928	fd://29	unix:///run/nfd.sock	local	on-demand	point-to-point	Never	2	0	926	0	2	1698
3175	udp4://129.82.138.48:6363	udp4://0.0.0.0:6363	non-local	persistent	point-to-point	Never	670162	57470	103380182	413433	60383	118123767
3298	udp4://114.247.165.44:6363	udp4://0.0.0.0:6363	non-local	persistent	point-to-point	Never	233811	32984	57730408	583941	1	52743589
4247	fd://35	unix:///run/nfd.sock	local	on-demand	point-to-point	Never	3	0	137	0	2	974

Fig. 6. NFD status page in R3 to connect global NDN testbed

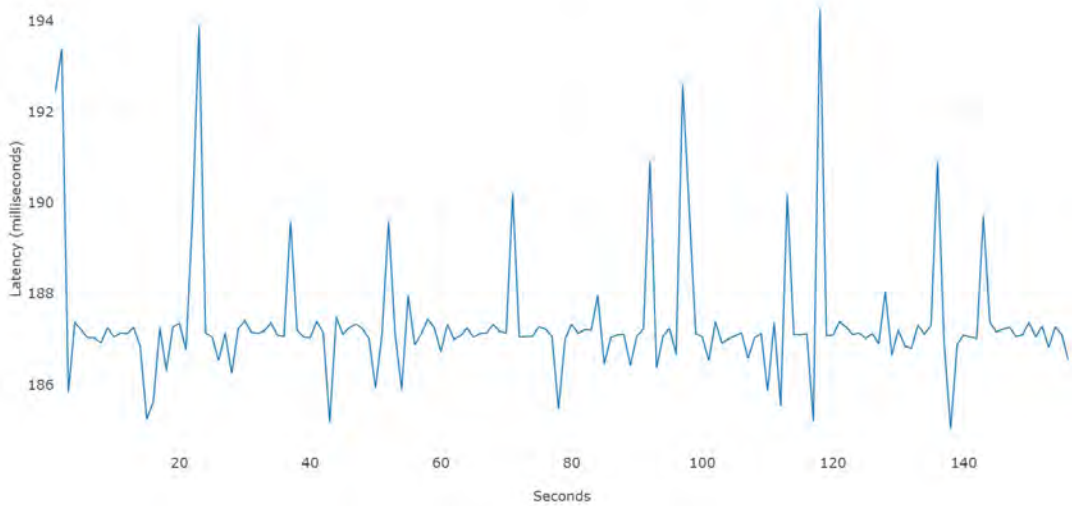

Fig. 8. Packet delivery latency graph by NDN ping test

```
root@router3:/home/kisti-ndn# ndnping /cmip5/csu

=== Pinging /cmip5/csu ===

Content From /cmip5/csu - Ping Reference = 1656078822   - Round Trip Time = 192.789 ms
Content From /cmip5/csu - Ping Reference = 1656078823   - Round Trip Time = 187.433 ms
Content From /cmip5/csu - Ping Reference = 1656078824   - Round Trip Time = 187.149 ms
Content From /cmip5/csu - Ping Reference = 1656078825   - Round Trip Time = 187.315 ms
Content From /cmip5/csu - Ping Reference = 1656078826   - Round Trip Time = 187.203 ms
Content From /cmip5/csu - Ping Reference = 1656078827   - Round Trip Time = 187.464 ms
Content From /cmip5/csu - Ping Reference = 1656078828   - Round Trip Time = 186.711 ms
Content From /cmip5/csu - Ping Reference = 1656078829   - Round Trip Time = 185.781 ms
```

Fig. 9. NDN ping test result between KISTI and CSU

interest and data packets were sentthrough the UDP tunnel, so the face that was used in experiment was IP address of the producer. That is different from the faces that we are using for local connection.

Figure 8 represents latency between KISTI and CSU NDN testbed in form of linear graph. Latency is presented as blue line, which increase or decrease depends on each packet round trip time. The result shows packet delivery latencies without any losses in the meantime. In figure 8, packet delivery latency had the highest point by 200 ms and the lowest one by 185 ms. The average delivery latency from repeated experiments was 192 ms.

Fig. 9 shows content names of data packets and their round trip times, which is summed time of interest and data packet delivery time.

Ⅴ. Conclusion and Future Work

We have established an NDN testbed with global NDN connection using the NDN software platform. Global NDN testbed status with our NDN node participation was addressed. To verify the reachability on our NDN connections to global NDN testbed, a latency result is presented using NDN ping test.

Our future work is to develop a User Interface (UI) and translator that will be able to convert climate data files into NDN names/prefixes for climate modeling data (CMIP5) and vise versa, and to integrate them into the established NDN testbed.

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