

CCNx-based Cloud-Native Function: Networking and Applications

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National Institute of Information and Communications Technology (NICT), Japan

19-21 Sept. 2022

Contents of this tutorial

Check the detailed information of the tutorial in the web*

Half-day Tutorial: CCNx-based Cloud-Native Function: Networking and Applications

Monday, September 19, 2022 8:00 - 11:00 JST

8:00 - 11:00 JST: Half-day Tutorial: CCNx-based Cloud-Native Function: Networking and Applications

(8:00 - 9:30 JST)

Part 1: Cefore and its Integration with Docker Platforms



This part focuses on the networking aspect of CCNx-based communications. We first introduce Cefore, a software platform enabling CCNx-based communications, and briefly explain the Docker platform. We then explore Cefore integration with Docker through some sample scenarios and introduce methods for quick/scalable construction of CCNx-based networks.

9:30 - 9:40 JST: Break

(9:40 - 10:40 JST)

Part 2: Cefpyco: Python Compact Package for Developing Cefore Applications



This part focuses on the applications aspect of CCNx-based communications. We introduce the features of Cefpyco and explain how to use it.

Q&A

*<https://conferences2.sigcomm.org/acm-icn/2022/tutorial-cefore.html>

Cefore and its Integration with Docker Platforms

Yusaku Hayamizu, Atsushi Ooka, Kazuhisa Matsuzono, Hitoshi Asaeda

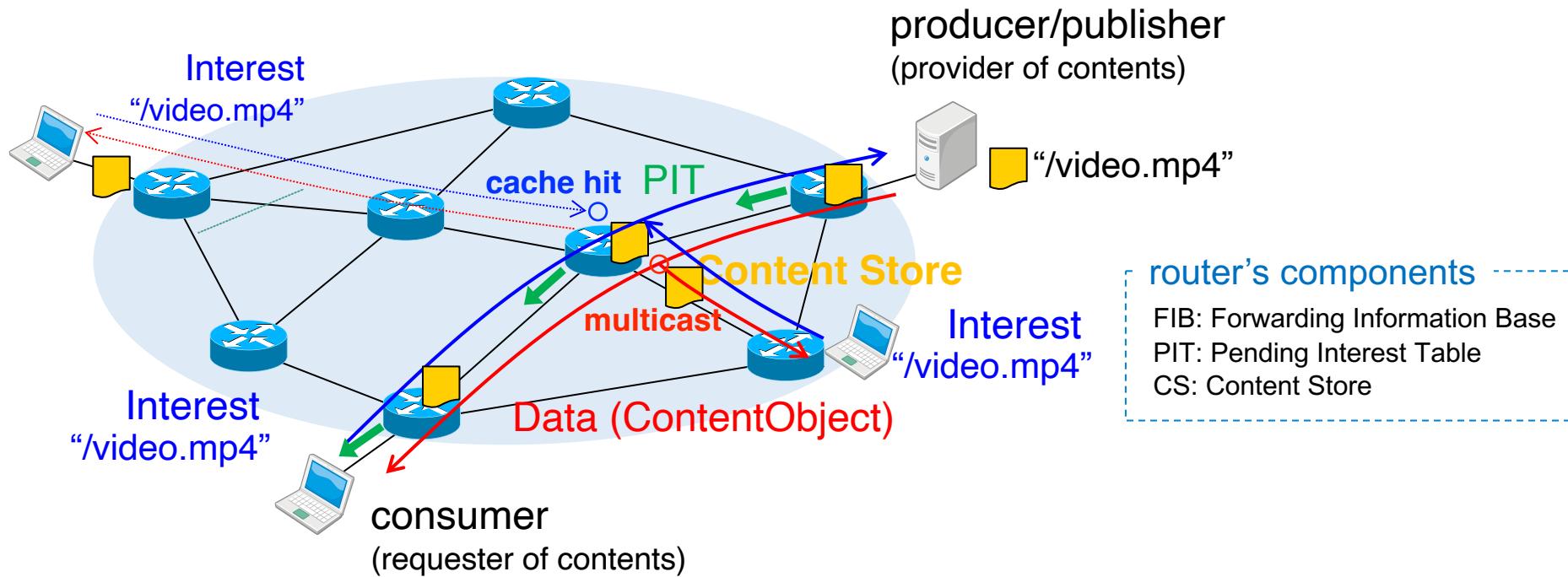
National Institute of Information and Communications Technology (NICT), Japan

19-21 Sept. 2022

- Background/Motivation
- Cefore: CCNx-based Extensible Packet Forwarding Engine
- Cefore x Docker Integration
- Sample Scenarios
- Conclusion

- **Information-Centric Networking [1]**

- A user retrieves information (contents) by name instead of host ID e.g. IP address
- in-network caching (CS: Content Store) enables efficient information delivery
- supports multicast communications by Interest aggregation



- ICN [1]
 - changing NW from “*host-centric*” to “*content-centric*”
- CCNx [2,3] / NDN [4]
 - Content-Centric Networking or Named-Data Networking
- Cefore [8]
 - open-source software enabling ICN communications
 - CCNx1.0-compliant packet forwarding engine developed/maintained by NICT
- One missing piece might be...
 - a deployment solution of developed ICN modules into the Internet infrastructures

1. Introduction of Cefore
 - the Cefore software platform for enabling CCNx-based communications
2. Cefore/Docker integration
 - Cefore's integration with the emerging Docker technologies for rapid and scalable deployment of ICN
 - NETWORKING
3. Application development with Cefpyco*
 - a Python wrapper program that helps developing CCNx applications
 - APPLICATION

*NOTE: 2nd speaker will present this part

Cefore: CCNx-based Extensible Packet Forwarding Engine



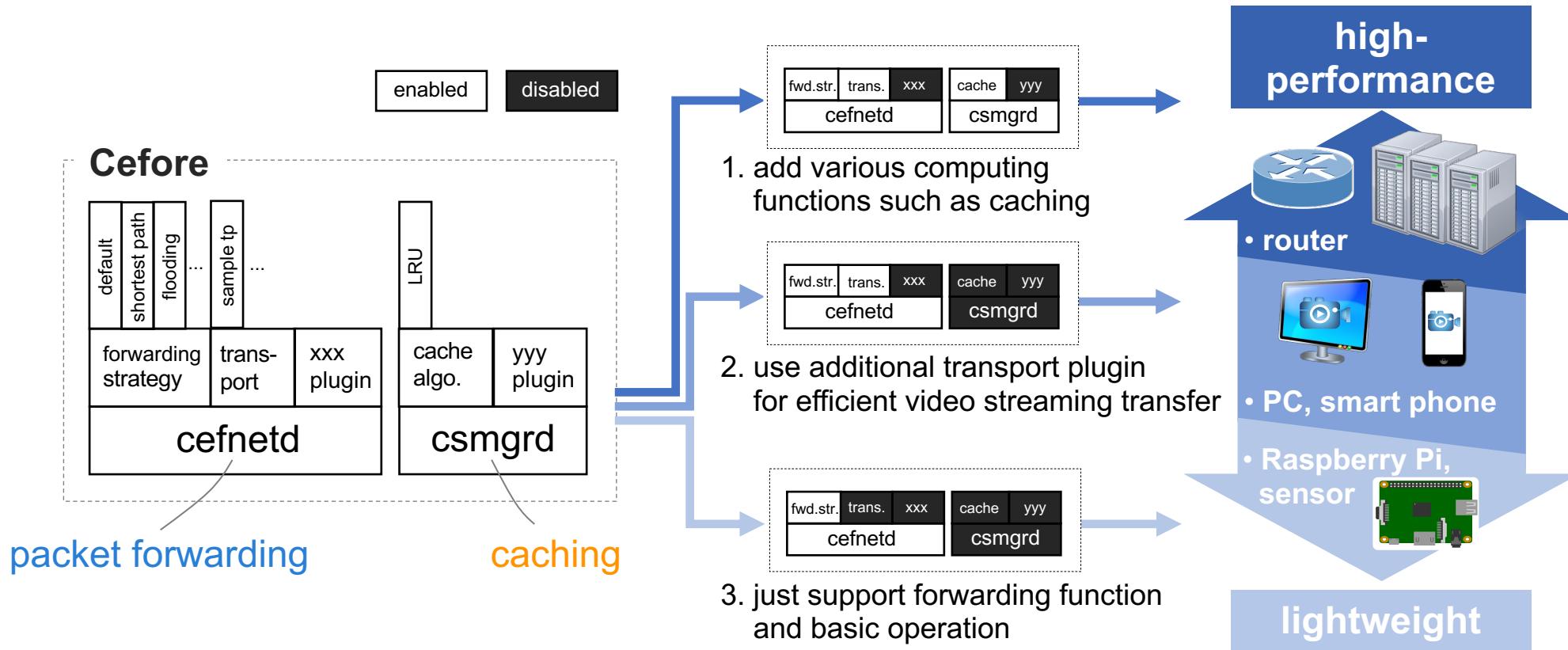
- CCNx1.0
 - defined in the RFCs 8569 and 8609
 - standardized by IRTF ICNRG
- Cefore
 - originally designed in 2016
 - CCNx1.0 packet (Interest/ContentObject) forwarding/caching engine
 - developed / maintained by NICT
 - open-source, and published in the web* and github⁺

* <https://cefore.net/>

⁺ <https://github.com/cefore>

- Lightweight
 - the software implementation should be compact
 - the platform should be usable for resource-constrained devices, such as sensor nodes
- Usability
 - the platform should be easily configured, set up, reloaded, and connected to the experimental environments
 - Ideally, its emulation / simulation should be easily conducted and tested using real network equipment
- Extensibility
 - the platform should be easily extensible to accommodate novel functions to satisfy future network needs

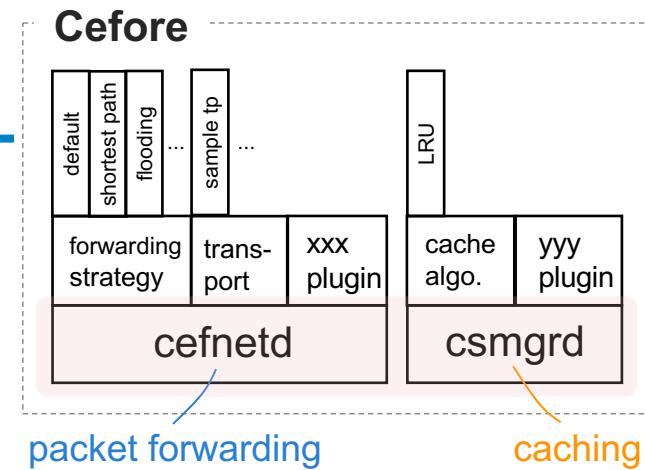
Pluggable architecture of Cefore



- Researchers can install necessary ICN functions depending on their requirements while considering their machine resource constraints

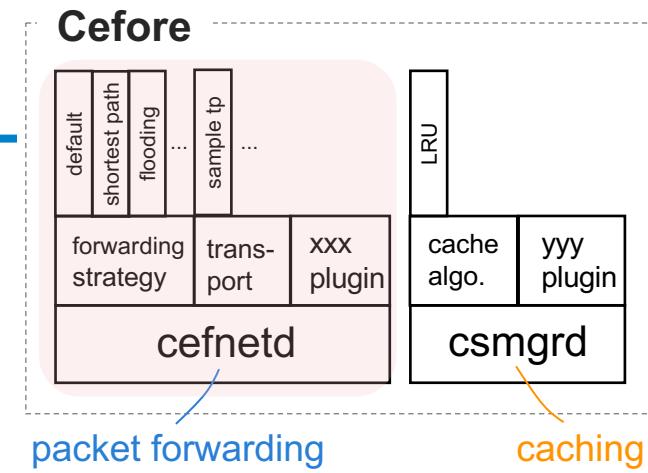
Core components

- cefnetd
 - handles Interest & ContentObject packets as the core packet forwarding daemon
 - a minimum set of ICN functions (FIB&PIT) to achieve the lightweight implementation
 - other compute-intensive functions (e.g. caching and computing) are implemented using plugins or external daemons for providing extensibility and usability
 - [optional] lightweight local-caching function
- csmgrd
 - an external cache daemon interacting with cefnetd, behaving as Content Store (CS)
 - connects to cefnetd via a local socket or TCP
- configuration
 - cefnetd.conf/csmgrd.conf
 - we can tune-up parameters dominant for network performance such as FIB/PIT size, CS capacity, etc.



Plugin extension 1: cefnetd

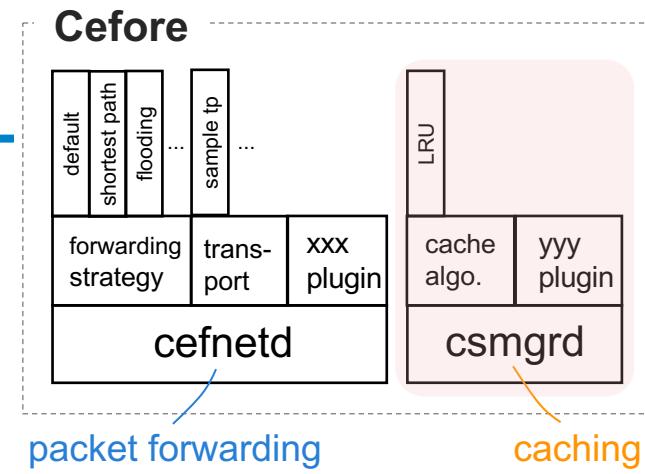
- forwarding strategy plugin
 - default
 - shortest_path
 - flooding
 - etc
- transport plugin
 - sample tp
 - etc
- xxx plugin
 - new plugins developed in the future



- Researchers can develop new mechanisms without modifying codes of the core daemons, i.e., cefnetd/csmgrd by using plugin extension
- Researchers can freely modify and create another “forwarding-strategy/transport” plugin

Plugin extension 2: csmgrd

- cache plugin
 - FIFO: First-In, First-Out
 - LRU: Least Recently Used
 - LFU: Least Frequently Used
- yyy plugin
 - new plugins developed in the future



- Researchers can develop new mechanisms without modifying codes of the core daemons, i.e., cefnetd/csmgrd
- Researchers can freely modify and create another “cache” plugin

- cefgetfile
 - consumer-like application
 - a sample program for downloading a named content with simple Interest pipelining
 - uses Regular Interest (RGI) for data retrieval

- cefputfile
 - producer-like application
 - a sample program for uploading a named content to CS (csmgrd) running on the localhost
 - ContentObject packets are delivered from the CS to the consumer running cefgetfile

- cefgetstream
 - a consumer-like application
 - a sample program for receiving stream data, e.g. real-time video streaming
 - uses Symbolic Interest* for efficient data transfer of the streaming content
- cefputstream
 - a producer-like application
 - a sample program for sending stream data to downward nodes
 - can control the sending rate of data stream with -r option

*K. Matsuzono, H. Asaeda and T. Turletti, ``Low latency low loss streaming using in-network coding and caching," IEEE INFOCOM 2017, IEEE Conference on Computer Communications, 2017, pp. 1-9, doi: 10.1109/INFOCOM.2017.8057026.

- CCNinfo*
 - CCNx network management tool
 - discovery detailed information of CCNx network
 - routing path information
 - RTT between the content forwarder (cache/producer) and the consumer
 - states of in-network cached content (lifetime, etc)
 - the specification is defined in the IRTF ICNRG [10]

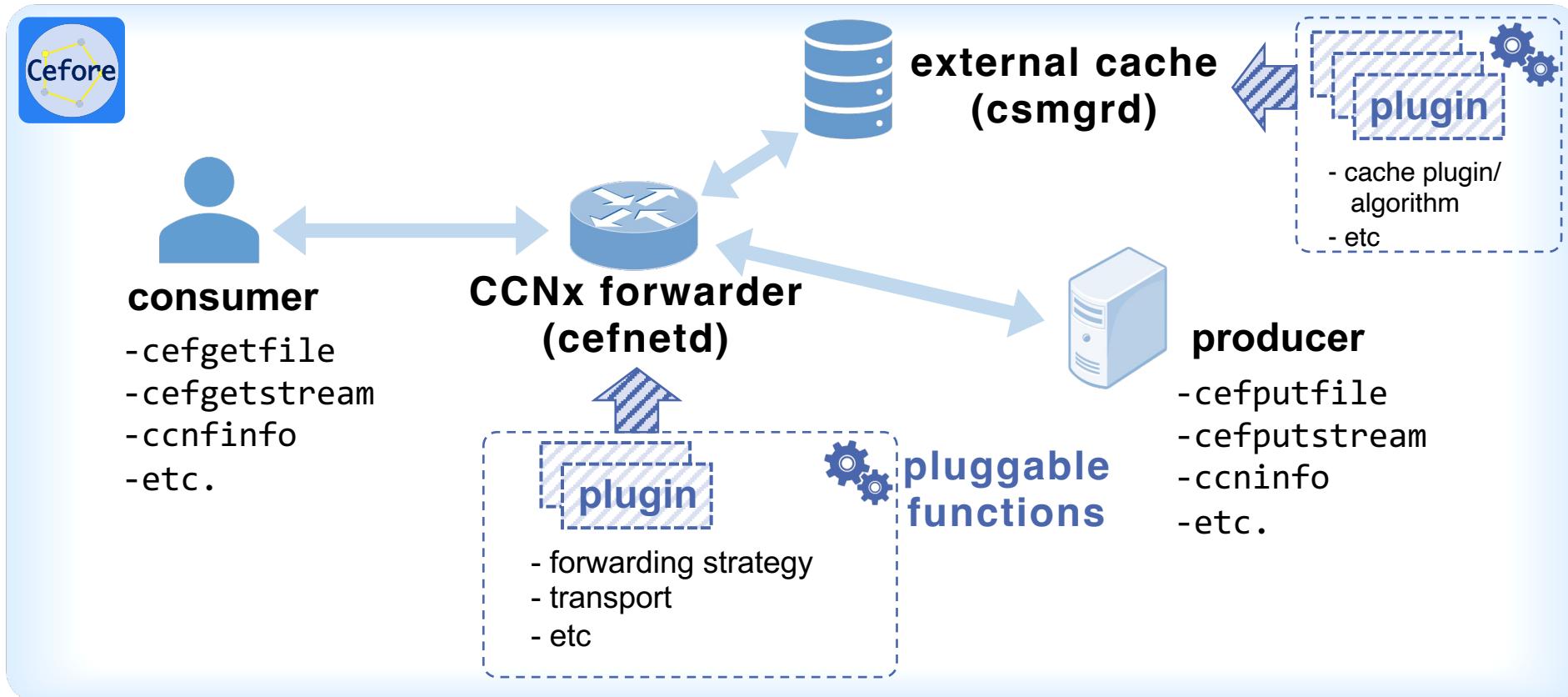
*<https://datatracker.ietf.org/doc/draft-irtf-icnrg-ccninfo/>

Name/Item	Type	Option	Description
cefnedt	daemon	Standard	Forwarding daemon
cefnedtstart	utility	Standard	Utility of starting cefnедt
cefnedtstop	utility	Standard	Utility of stopping cefnедt
cefstatus	utility	Standard	Utility of showing cefnедt status on stdout
cefroute	utility	Standard	Utility of set up cefnедt FIB
cefctrl	tool	Standard	Function called by cefnедtstop, cefstatus, and cefroute
cefgetchunk	tool	Standard	Obtain the specified Cob and show the payload on stdout
cefputfile	tool	Standard	Convert the file to Named Cobs and transmit them to Cefore
cefgetfile	tool	Standard	Create file from content received by Cefore
cefputstream	tool	Standard	Convert the stream received from stdin to Named Cobs and transmit them to Cefore
cefgetstream	tool	Standard	Display the stream received by Cefore on stdout
cefputfile_sec	tool	develop	Obtain security content from Cefore and output it as a file
cefgetfile_sec	tool	develop	Convert a file to Named Cob with security features and input it into Cefore
cefping	tool	cefping	cefping
cefinfo	tool	cefinfo	cefinfo (aka ccninfo)
csmgrd	daemon	csmgr	Content Store manager daemon
csmgrdstart	utility	csmgr	Utility of starting csmgr daemon
csmgrdstop	utility	csmgr	Utility of stopping csmgr daemon
csmgrstatus	utility	csmgr	Utility of showing csmgrd status on stdout
Sample Transport	plugin	samptp	Sample transport plugin library
cefore.lua	application	Standard	Wireshark's LUA script file

*Details can be found at: <https://cefore.net/doc/Readme.html>

“All-in-one package” for CCNx-based communications

- Cefore provides “all-in-one package”



Related software program: Cefpyco

- Cefpyco (CEFore Python Compact package)*
 - a Python-based wrapper program that help developing CCNx applications running with Cefore
 - enables easy coding for python programmers (compared to the original C language)
 - Example: sending an Interest packet

C language

```
1 #include <stdio.h>
2 #include <stdlib.h>
3 #include <unistd.h>
4 #include <ctype.h>
5 #include <cefore/cef_define.h>
6 #include <cefore/cef_client.h>
7 #include <cefore/cef_frame.h>
8 #include <cefore/cef_log.h>
9
10 int main(int argc, char *argv[]) {
11     CefT_Client_Handle fhdl;
12     CefT_Interest_TLVs params_i;
13     int res;
14     cef_log_init ("cefpyco");
15     cef_frame_init();
16     res = cef_client_init(port_num, conf_path);
17     if (res < 0) return -1;
18     fhdl = cef_client_connect();
19     if (fhdl < 1) return -1;
20     memset(&params_i, 0, sizeof(CefT_Interest_TLVs));
21     res = cef_frame_conversion_uri_to_name("ccnx:/test",
22     params_i.name);
23     if (res < 0) return -1; // Failed to convert URI to name.;
24     params_i.name_len = res;
25     params_i.hoplimit = 32;
26     params_i.opt.lifetime_f = 1;
27     params_i.opt.lifetime = 4000ull; /* 4 seconds */
28     params_i.opt.symbolic_f = CefC_T_OPT_REGULAR;
29     params_i.chunk_num_f = 1;
30     params_i.chunk_num = 0;
31     cef_client_interest_input(fhdl, &params_i);
32     if (fhdl > 0) cef_client_close(fhdl);
33 }
```

33 lines
-> 4 lines

Python

```
1 import cefpyco
2
3 with cefpyco.create_handle() as h:
4     h.send_interest("ccnx:/test", 0)
```

NOTE: the 2nd speaker will deliver the presentation about Cefpyco in detail

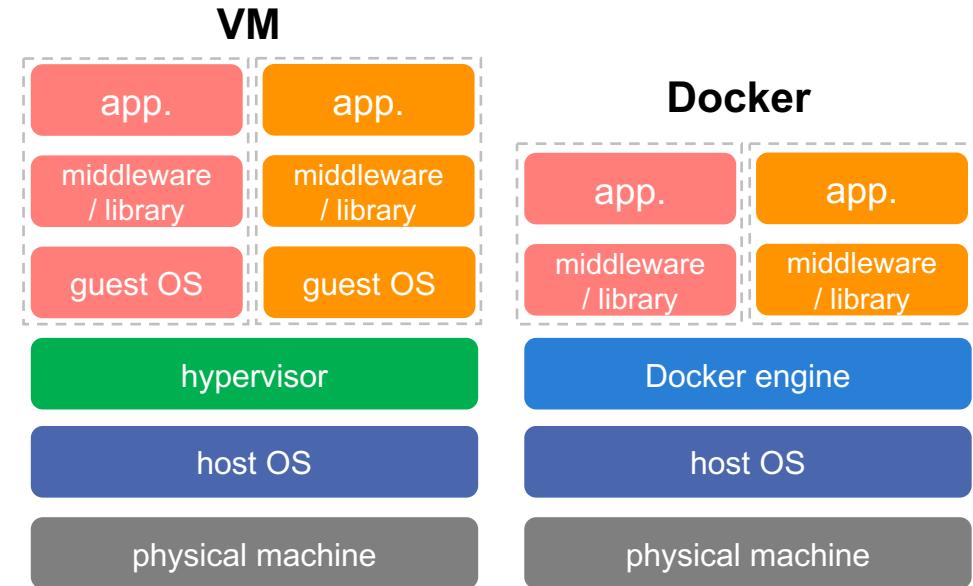
*<https://github.com/cefore/cefpyco>

- OS
 - Linux (Ubuntu 18.04 or later)
 - macOS (10.15 or later)
- Packet format
 - CCNx1.0
 - Type-Length-Value (TLV) format
 - NICT original functions -> Optional Hop-by-hop header
- Networking
 - TCP/UDP over IP (overlay)

Cefore x Docker Integration



- Docker
 - a platform of container-based virtualization technology for quick and scalable deployment of network services
- Benefits
 - Lightweight
 - a Docker container is very lightweight compared with VM
 - -> we can build many containers in one physical machine
 - -> this enriches evaluation scenario of ICN networks and improves scalability of experiments
 - Performance
 - Docker containers do not contain OS
 - -> they can be easily and quickly initiated and terminated
 - -> this facilitates comfortable test and evaluation of ICN services
 - Scalability
 - there is a requirement that multiple ICN nodes providing different functions co-exist in a network
 - the concept of microservices that each service image is built for each purpose fits this requirement
 - useful option tools such as docker-compose can be used for flexibly and quickly setting up Docker containers



comparison of VM and Docker



- Ubuntu 20.04
 - follow the official introduction
 - <https://docs.docker.com/engine/install/ubuntu/>
- macOS
 - web
 - <https://www.docker.com/products/docker-desktop/>
 - CUI

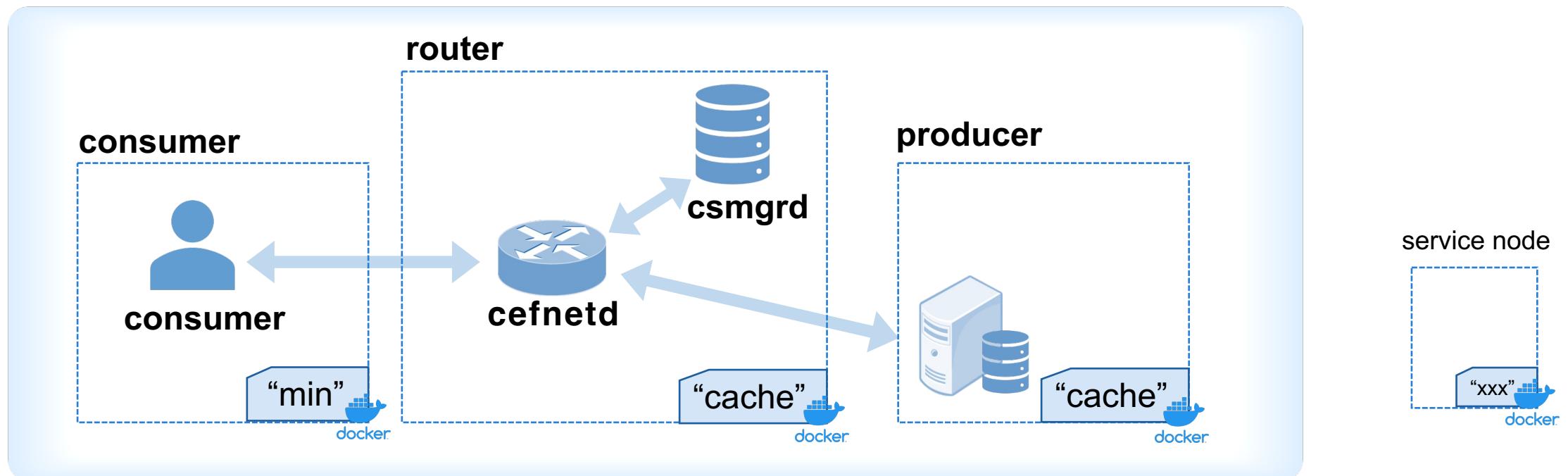
```
cefore ~ % brew install docker [--cask]
cefore ~ % open /Applications/Docker.app
```
- Windows
 - web
 - <https://www.docker.com/products/docker-desktop/>

- CPU
 - min: 4 cores
 - recommended: 8 cores
- * for macOS, the Intel chips are recommended not the Apple silicon chips (M1/M2)
- Memory
 - min: 4 GB
 - recommended: 8 GB

NOTE: The host machine spec should be considered according to the scenario of experiments which you want to run with docker containers.

Example scenario of Cefore/Docker-based networking

- Scenario
 - The consumer requests a file
 - The producer responses to the request and send back data
 - The CCNx router stores received data into CS (csmgrd)



Example 1 – writing a Dockerfile

- define a microservice as a ``base'' service
 - base function as an ICN node
 - necessary functions for providing ICN services as a container node

base/Dockerfile

```
FROM ubuntu:20.04
LABEL maintainer="hayamizu <hayamizu@nict.go.jp>"
RUN mkdir -p /cefore
WORKDIR /cefore
RUN apt update
RUN apt install -y git build-essential libssl-dev automake
RUN apt -y clean
RUN git clone https://github.com/cefore/cefore.git
WORKDIR /cefore/runner_test
```

install basic libraries for building Cefore

download the Cefore software from the github

Afterward, other enhanced ICN services, e.g. ``min'' and ``cache,''
inherit this ``base'' image

Example 2 – writing a Dockerfile

- define a microservice as a ``min'' service
 - minimum functions serving as a ICN node, i.e., installation & app. preparation

min/Dockerfile

```
FROM cefore/base
WORKDIR /cefore/cefore
RUN ./configure
RUN make; make install; make clean
RUN ldconfig
ENV USER root
COPY ./entrypoint.bash /cefore
ENTRYPOINT /cefore/entrypoint.bash
```

← configure & make & install Cefore

← set the entrypoint, i.e., just starting Cefore daemon
(cefnetd)

define a service “min” that provide minimum ICN functions (application tools)

Example 3 – writing a Dockerfile

- define a microservice as a ``cache” service

cache/Dockerfile

```
FROM cefore/base
WORKDIR /cefore/cefore
RUN ./configure --enable-cache --enable-csmgr
RUN make; make install; make clean
RUN ldconfig
RUN echo "CS_MODE=2" > /usr/local/cefore/cefnetd.conf
RUN echo "CACHE_TYPE=memory" > /usr/local/cefore/csmgrd.conf
ENV USER root
COPY ./entrypoint.bash /cefore
ENTRYPOINT /cefore/entrypoint.bash
```

configure Cefore by enabling ``csmgr/cache” option

make & install Cefore

modify the configuration files.

CS_MODE=2 (csmgrd)

CACHE_TYPE=memory

set the entrypoint, i.e., starting Cefore daemons
(cefnetd & csmgrd)

define “cache” service by adding caching function (cache/csmgrd) to the base ICN functions



- docker-compose
 - a tool for defining and running multi-container Docker applications
 - easy service configuration using a YAML file
 - can create and start all the services from the configuration with a single command
- > easy to conduct scenario-based experiments(emulations)
like network simulations such as ns-3

*<https://docs.docker.com/compose/>

Example: docker-compose.yml

```
version: "3.3"
services:
  producer:
    image: cefore/cache
    container_name: "producer"
    hostname: "producer"
    working_dir: "/cefore"
    networks:
      downward:
        ipv4_address: 10.0.1.10
  router:
    image: cefore/cache
    container_name: "router"
    hostname: "router"
    working_dir: "/cefore"
    networks:
      downward:
        ipv4_address: 10.0.1.20
  consumer:
    image: cefore/min
    container_name: "consumer"
    hostname: "consumer"
    working_dir: "/cefore"
    networks:
      downward:
        ipv4_address: 10.0.1.100
networks:
  downward:
    name: downward
    driver: bridge
    ipam:
      driver: default
      config:
        - subnet: 10.0.1.0/24
```

Cefore/Docker Basic Operation

- Downloading source codes
 - <https://cefore.net/>
 - <https://github.com/cefore/cefore>
- Installing dependencies

```
$ sudo apt-get install libssl-dev automake
```

- Installing Cefore

```
$ unzip cefore-0.9.0b.zip
$ cd cefore-0.9.0b
$ autoconf
$ automake
$ ./configure --enable-csmgr --enable-cache
$ make
$ sudo make install
$ sudo ldconfig          # binaries are to be installed in the /usr/local/bin, sbin
```

Please see more details Section 2 “Installation” of README.
*<https://cefore.net/doc/Readme.html>

Starting Docker containers

- Build a Docker image

```
% docker build -f Dockerfile -t cefore/base
```

- Check the status of built container images

```
% docker images
REPOSITORY      TAG      IMAGE ID      CREATED      SIZE
cefore/cache    latest   59ef9d12b859  12 minutes ago  881MB
cefore/min      latest   935747e7cc84  12 minutes ago  881MB
cefore/base     latest   3694f2af7dd7  13 minutes ago  873MB
```

- Start a container

```
% docker run --name consumer -it IMAGE_ID /bin/bash
root@7db7391ba03c:/cefore/runner_test#
```

- Login to the container (NOTE: run ``exec'' command in another terminal)

```
% docker exec -it consumer /bin/bash
root@7db7391ba03c:/cefore/runner_test#
```

Stopping Docker containers

- Stop a Docker container

```
root@5d731a71974f:/cefore/cefore# exit
```

or

```
% docker stop CONTAINER_ID
```

- Remove a container

```
% docker rm -f CONTAINER_ID
```

- Remove a container image

```
% docker rmi IMAGE_ID
```

- Purge all the build cache and images*

```
% docker builder prune  
WARNING! This will remove all dangling build cache. Are you sure you  
want to continue? [y/N] y
```

* This command should be run carefully

- Start cefnetd

```
% cefnetdstart
```

- Stop cefnetd

```
% cefnetdstop
```

- Start csmgrd

```
% csmgrdstart
```

- Stop csmgrd

```
% csmgrdstop
```

NOTE: When you configure to use both cefnetd and csmgrd, first you need to start csmgrd, and then start cefnetd.

- Checking the status of cefnetd

- cefstatus

- CCNx ver.
 - Rx/Tx Interest #
 - Rx/Tx ContentObject #
 - Cache Mode
 - Face Table
 - FIB
 - PIT

- cefstatus -v

- confirm the version of Cefore running on the container

```
root@router:/cefore# cefstatus
Version : 1
Port : 9896
Rx Interest : 0 (RGL[0], SYM[0], SEL[0])
Tx Interest : 0 (RGL[0], SYM[0], SEL[0])
Rx ContentObject : 0
Tx ContentObject : 0
Cache Mode : Excache
Faces : 6
  faceid = 4 : IPv4 Listen face (udp)
  faceid = 0 : Local face
  faceid = 5 : IPv6 Listen face (udp)
  faceid = 6 : IPv4 Listen face (tcp)
  faceid = 16 : Local face
  faceid = 7 : IPv6 Listen face (tcp)
FIB(App) :
  Entry is empty
FIB :
  Entry is empty
PIT(App) :
  Entry is empty
PIT :
  Entry is empty
```

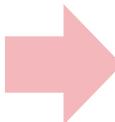
```
root@consumer:/cefore# cefstatus -v
Cefore version 0.9.0b
```

Checking the status of csmgrd

- Checking the status of csmgrd
 - csmgrstatus NAME_PREFIX

+ initial state

```
root@producer:/cefore# csmgrstatus ccnx:/  
  
Connect to 127.0.0.1:9799  
***** Connection Status Report *****  
All Connection Num : 1  
  
***** Cache Status Report *****  
Number of Cached Contents : 0
```



+ after putting the 3 contents

```
root@producer:/cefore# csmgrstatus ccnx:/  
  
Connect to 127.0.0.1:9799  
***** Connection Status Report *****  
All Connection Num : 1  
  
***** Cache Status Report *****  
Number of Cached Contents : 3  
  
[0]  
Content Name : ccnx:/ccc  
Version : None  
Content Size : 4 Bytes  
Cache Hit : 0  
Request Count : 0  
Freshness : 290 Sec  
Elapsed Time : 8 Sec  
  
[1]  
Content Name : ccnx:/bbb  
Version : None  
Content Size : 4 Bytes  
Cache Hit : 0  
Request Count : 0  
Freshness : 283 Sec  
Elapsed Time : 14 Sec  
  
[2]  
Content Name : ccnx:/aaa  
Version : None  
Content Size : 4 Bytes  
Cache Hit : 0  
Request Count : 0  
Freshness : 275 Sec  
Elapsed Time : 22 Sec
```

+ specify name prefix

```
root@producer:/cefore# csmgrstatus ccnx:/aaa  
  
Connect to 127.0.0.1:9799  
***** Connection Status Report *****  
All Connection Num : 1  
  
***** Cache Status Report *****  
Number of Cached Contents : 1  
  
[0]  
Content Name : ccnx:/aaa  
Version : None  
Content Size : 4 Bytes  
Cache Hit : 0  
Request Count : 0  
Freshness : 268 Sec  
Elapsed Time : 29 Sec
```

- **cefroute**
 - **Insertion**
 - `cefroute add ccnx:/aaa udp 10.0.0.1`
 - **Deletion**
 - `cefroute del ccnx:/aaa udp 10.0.0.1`
- Alternative: preparing an FIB configuration file
 - `/usr/local/cefore/cefnetd.fib`
 - `cefnetd` automatically loads this file when starting its process
- Routing Protocol
 - TBA

```
root@producer:/cefore# cat /usr/local/cefore/cefnetd.fib
ccnx:/example udp 10.0.1.1
```

+ Setting FIB using cefnetd.fib

```
root@producer:/cefore# cefstatus
Version      : 1
Port         : 9896
Rx Interest   : 0 (RGL[0], SYM[0], SEL[0])
Tx Interest   : 0 (RGL[0], SYM[0], SEL[0])
Rx ContentObject : 0
Tx ContentObject : 0
Cache Mode    : Excache
Controller    : 192.168.0.99
Faces : 7
  faceid = 4 : IPv4 Listen face (udp)
  faceid = 0 : Local face
  faceid = 16 : address = 10.0.1.1:9896 (udp)
  faceid = 17 : Local face
  faceid = 5 : IPv6 Listen face (udp)
  faceid = 6 : IPv4 Listen face (tcp)
  faceid = 7 : IPv6 Listen face (tcp)
FIB(App) :
  Entry is empty
FIB : 1
  ccnx:/example
    Faces : 16 (-s-) RtCost=0
PIT(App) :
  Entry is empty
PIT :
  Entry is empty
```

- Primary parameters
 - cefnetd.conf
 - CS_MODE
 - 0: no content store [default]
 - 1: cefnetd's local cache
 - 2: external content store (csmgrd)
 - FORWARDING_STRATEGY
 - default: Forward the Interest to a face in the longest-prefix-matched(LPMed) FIB entry [default]
 - flooding: Forward the Interest to all the faces registered in the LPMed FIB entry
 - shortest_path: Forward the Interest to the face that has the minimum routing cost in the LPMed FIB entry
 - csmgrd.conf
 - CACHE_CAPACITY
 - The maximum number of cached ContentObjects in csmgrd
 - 819,200 [default]
 - CACHE_TYPE
 - filesystem: cache located on UNIX filesystem [default]
 - memory: cache located on memory (RAM)
 - CACHE_ALGORITHM
 - libcsmgrd_fifo
 - libcsmgrd_lru
 - libcsmgrd_lfu

Configuration parameters*

Parameter	Description	Default
CEF_LOG_LEVEL	Specifies the log output type for the cefnetd. Range: 0 <= n <= 3	0
PORT_NUM	Port number cefnetd uses. Range: 1024 < p < 65536 If the startup option "-p port_num" is used, the port number specified by the "-p port_num" option takes precedence over this parameter.	9896
PIT_SIZE	Max number of PIT entries. Range: 1 < n < 65536	2048
FIB_SIZE	Max number of FIB entries. Range: 1 < n < 65536	1024
CS_MODE	ContentStore mode Cefore uses.	0: No cache used 1: cefnetd's local cache 2: csmgrd
LOCAL_CACHE_CAPACITY	Max number of Cobs to use for the local cache in cefnetd. Range: 1 < n <= 8000000 Approximate memory usage: Cob size * 2 * num. of Cobs.	65535
CSMGR_NODE	csmgrd's IP address	localhost
CSMGR_PORT_NUM	TCP port number used by csmgrd to connect cefnetd. Range: 1024 < p < 65536	9799
FORWARDING_STRATEGY	Forwarding strategy when sending Interest messages. default : Forward the Interest to a face in the longest-prefix-matched (LPMed) FIB entry flooding : Forward the Interest to all the faces registered in the LPMed FIB entry shortest_path: Forward the Interest to the face that has the minimum routing cost in the LPMed FIB entry	0

*README is available at: <https://cefore.net/doc/Readme.html>

- Tuning socket buffer size
 - Ubuntu

```
$ sudo sysctl -w net.core.rmem_default=10000000
$ sudo sysctl -w net.core.wmem_default=10000000
$ sudo sysctl -w net.core.rmem_max=10000000
$ sudo sysctl -w net.core.wmem_max=10000000
```

- macOS

```
$ sudo sysctl -w net.local.stream.sendspace=10000000
$ sudo sysctl -w net.local.stream.recvspace=10000000
```

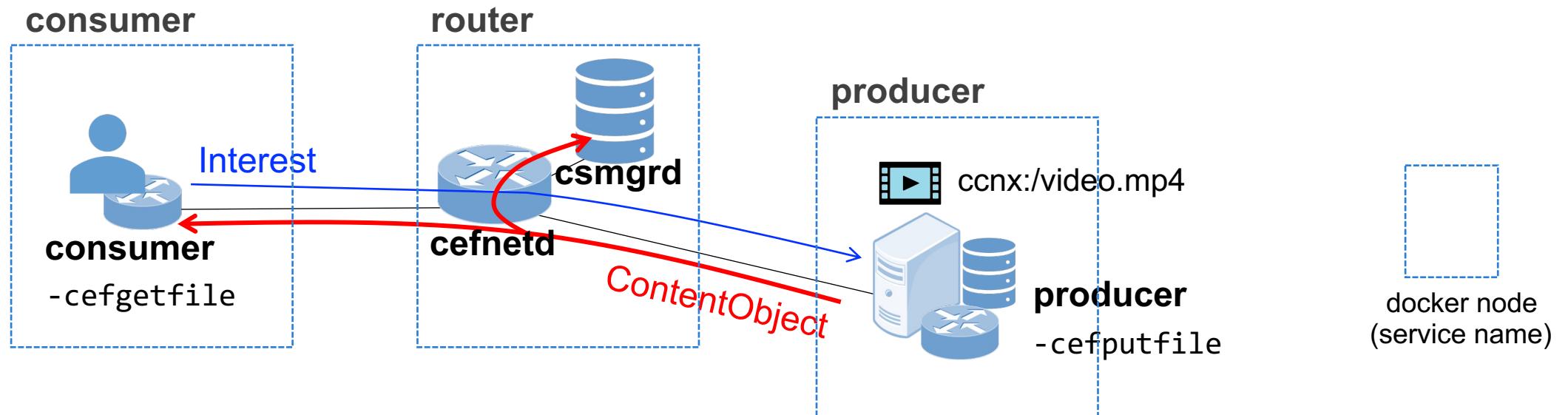
NOTE: Experientially, we would recommend to increase the socket buffer size of kernel parameters in advance, when you conduct an experiment with high-speed data rate.

Sample Scenarios



Click here.

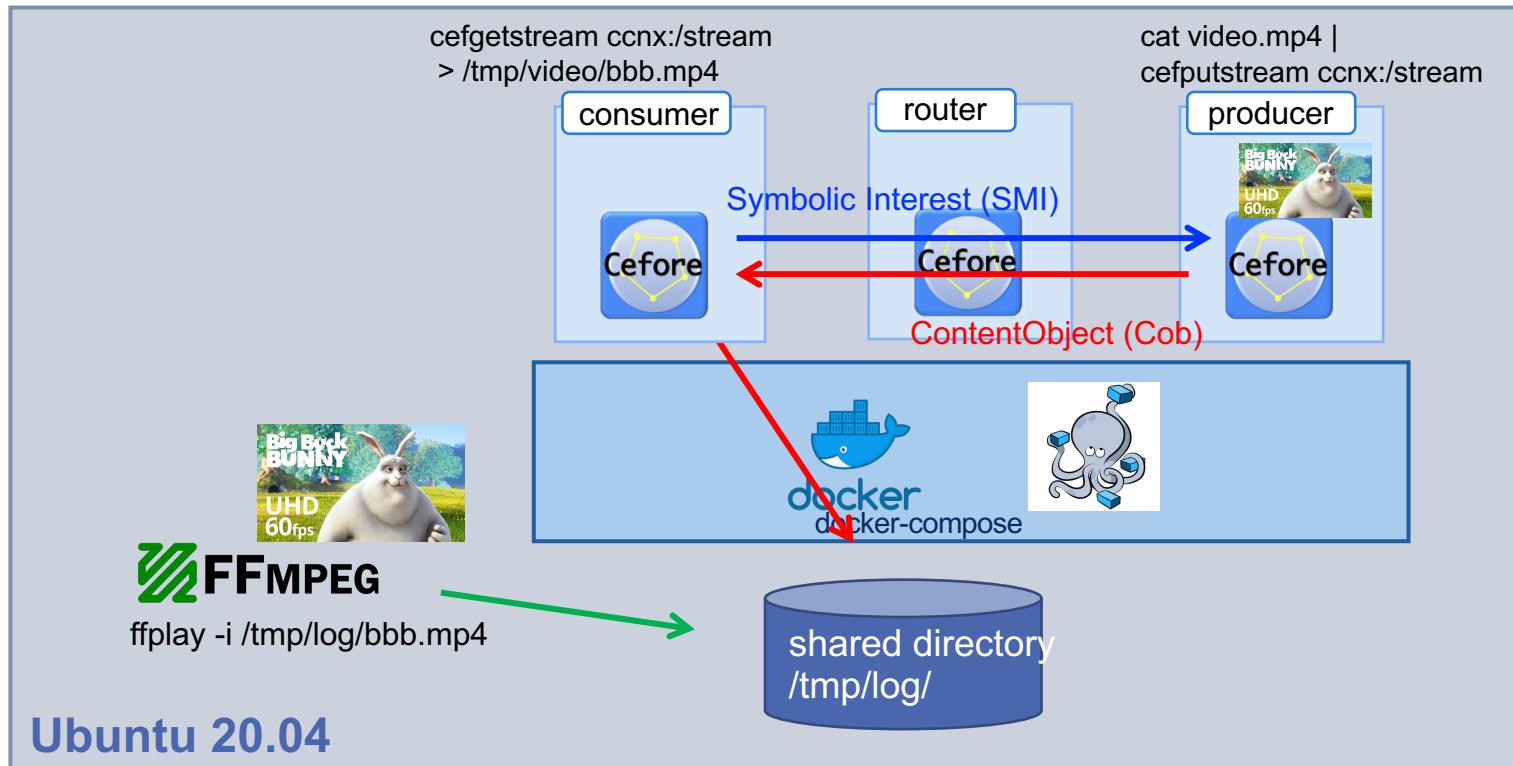
- Scenario
 - producer puts a video file (ccnx:/video.mp4) to its csmgrd with cefputfile
 - consumer requests the cached content with cefgetFile
 - check statistics information of consumer (throughput, latency, etc)
 - check the status of cefnetd/csmgrd in the router node





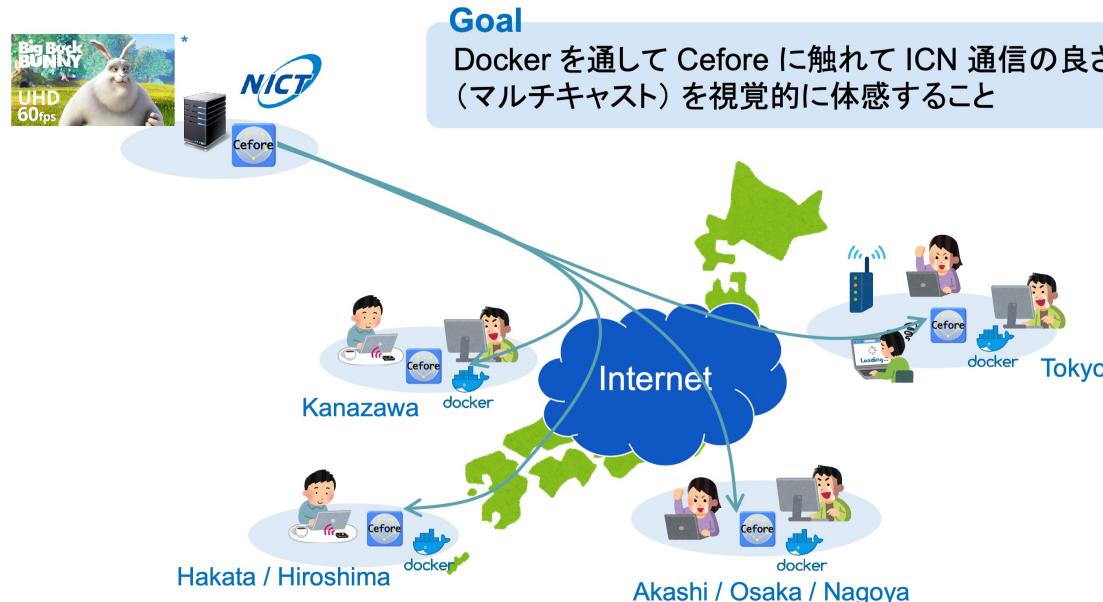
Click here.

- Scenario
 - producer publishes the stream data (video.mp4) toward the consumer with cefputstream
 - consumer sends Symbolic Interest to receive the data with cefgetstream
 - The host OS is waiting for the playback with ffplay in advance

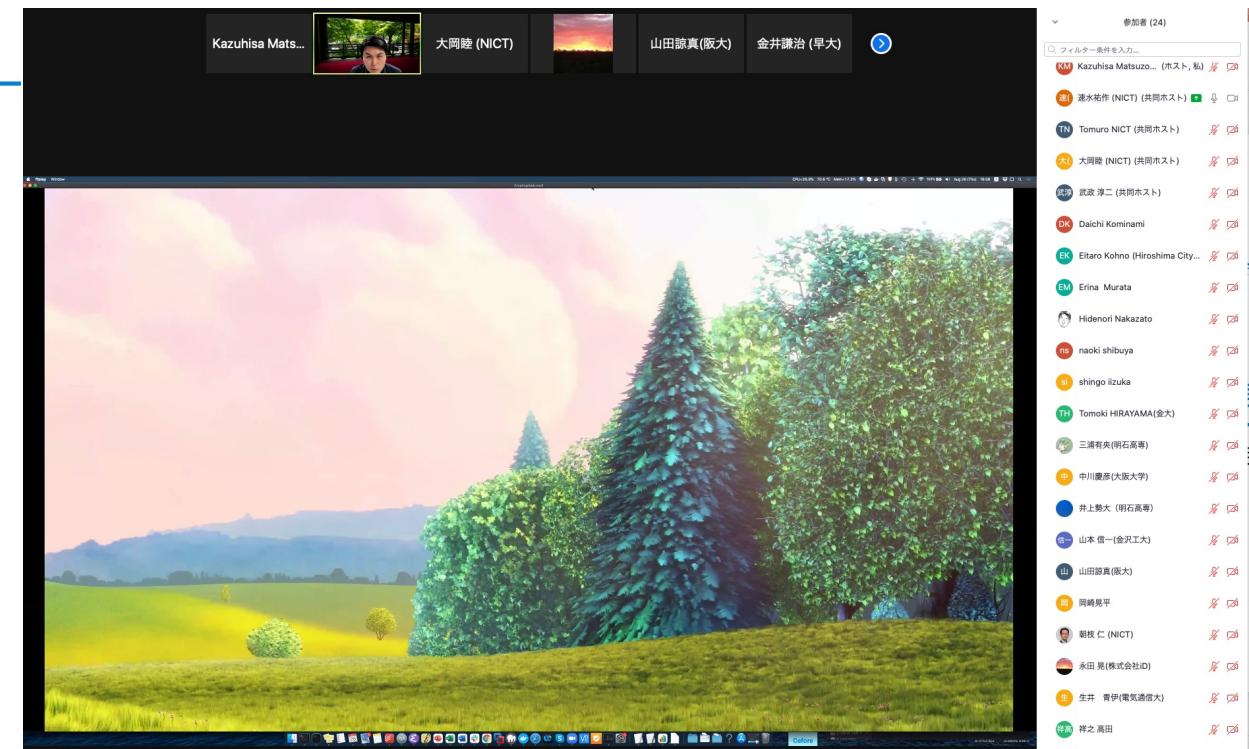


- IEICE ICN summer workshop 2021 [fully-online]
 - Cefore/Docker hands-on
 - Multicast video streaming using Cefore/Docker platforms*
 - The producer is located at NICT (Tokyo)
 - The consumers receive the video streaming from their homes/schools/companies

NICT PracticeA: Cefore/Docker を用いたマルチキャストストリーミング



* <https://peach.blender.org/>



* You can get sample codes from <https://github.com/cefore/2021-hands-on> [materials are in Japanese only]

- Cefore
 - CCNx-based extensible packet forwarding engine
 - All-in-one package for CCNx-based communications
- Docker integration
 - Quick and scalable deployment of CCNx functions
- Sample scenarios
 - File transfer
 - Video streaming
- Future work
 - A possibility of collaboration with the emerging Docker orchestration technologies such as Kubernetes

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- [2] “Content-Centric Networking (CCNx) Semantics,” <https://datatracker.ietf.org/doc/rfc8569/>, Accessed on 7 July 2022.
- [3] “Content-Centric Networking(CCNx)MessagesinTLVFormat,”<https://datatracker.ietf.org/doc/rfc8609/>, Accessed on 7 July 2022.
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- [5] “Docker,” <https://www.docker.com/>, Accessed on 7 July 2022.
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- [8] H.Asaeda,etal.,“Cefore: Software Platform Enabling Content-Centric Networking and Beyond,” IEICE Trans. Commun., vol.E102-B, no.9, pp.1792-1803, Sept. 2019.
- [9] “Cefpyco”, <https://github.com/cefore/cefpyco>, Accessed on 7 July 2022.
- [10] H. Asaeda, et al., “CCNinfo: Discovering Content and Network Information in Content-Centric Networks,” IRTF Internet-Draft, [draft-irtf-icnrg-ccninfo-10](https://datatracker.ietf.org/doc/draft-irtf-icnrg-ccninfo-10) (work in progress), Apr. 2022.

Thank you.

