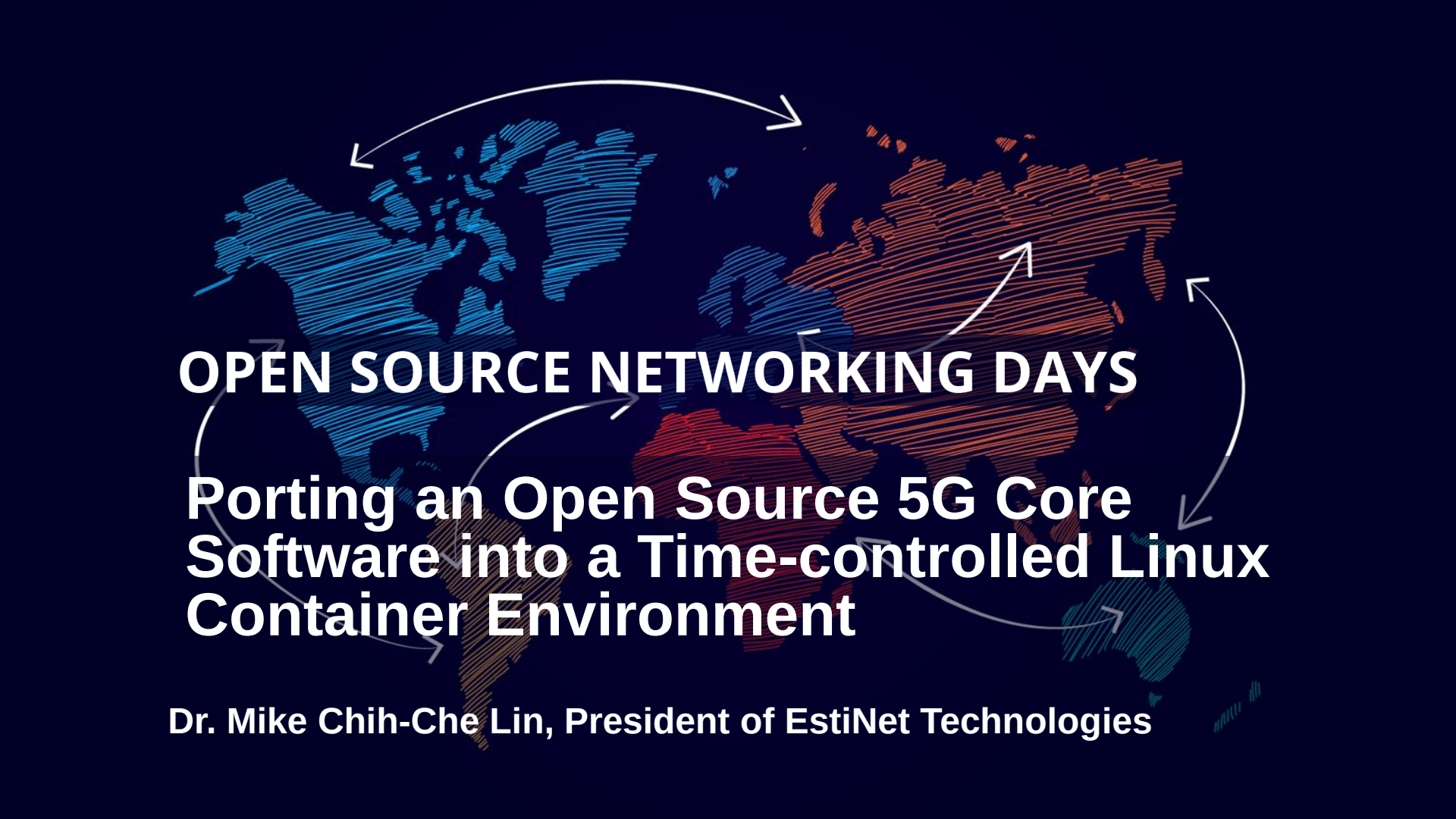


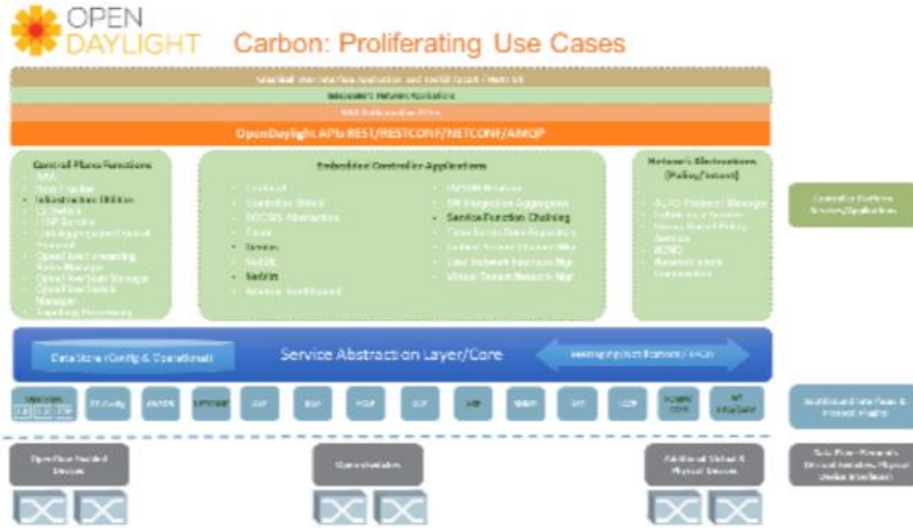
Porting an Open Source 5G Core Software into a Time-controlled Linux Container Environment

Dr. Mike Chih-Che Lin, President of EstiNet Technologies

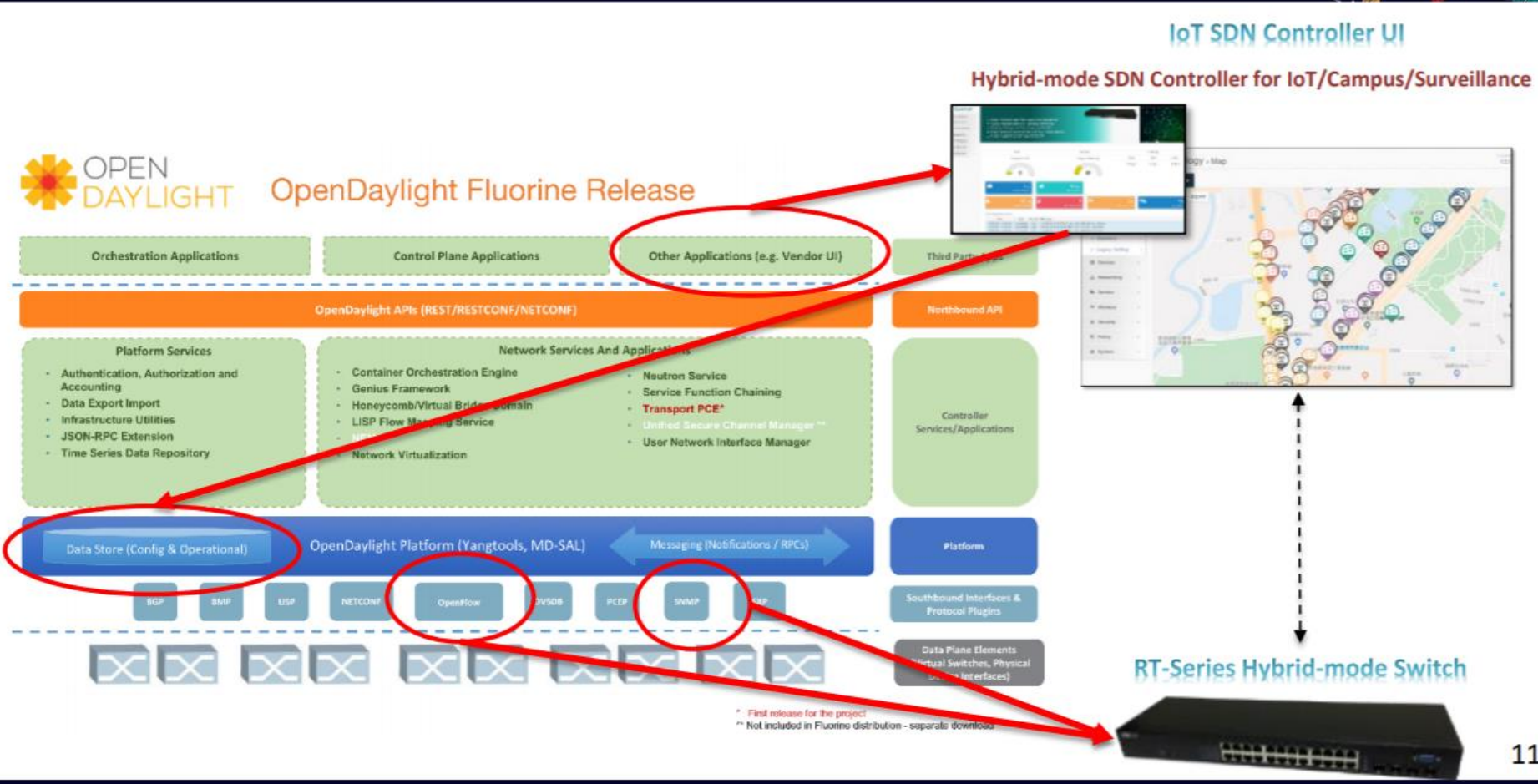
Our 2018 Work with Open Source Networking Projects

- **Enhanced from Open DayLight Controller**
  - **Hydrogen → Lithium → Carbon → Nitrogen → Oxygen**
- **Bugs fixed and new bundles (modules) added into the original open-sourced package**
- Provide **Restful North-bound API (NBI)** for upper-layer Management System
- Provide both **OpenFlow and SNMP Southbound APIs** for SDN devices (SDN Switches and IoT WiFi AP)
- Integrating common campus-level network services as NFVs
  - DHCP Server
  - Radius Server

Developed an IoT SDN Controller Platform based on Open DayLight for Smart City and edge networks



Overview of Our Changes to ODL

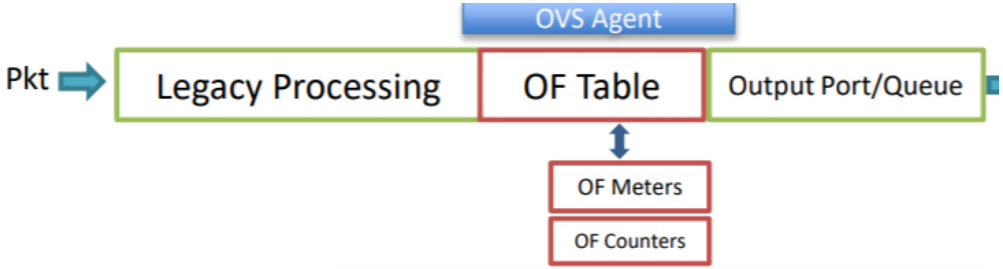


Implement OpenFlow Table Features on Domestic Realtek IC

- **24 1-Gbps Ethernet RJ-45 port**
- **POE port supported by RT188P**
- **4 1-Gbps SFP port**

Major Features

- Realtek RTL838-series ASIC inside
- Provide 1K flow entries
- Provide hardware-based meters
- Support OpenFlow 1.3 (47.8% compliance)
- Support OVS/OVSDB
- Support Legacy protocol suite (STP/RSTP/VLAN/QiniQ/IGMP/QoS)



OpenFlow Capability Detail:

Actions:
- Output
- Drop
- Push/Pop VLAN header
- Set IP DSCP
- Set VLAN VID/PCP

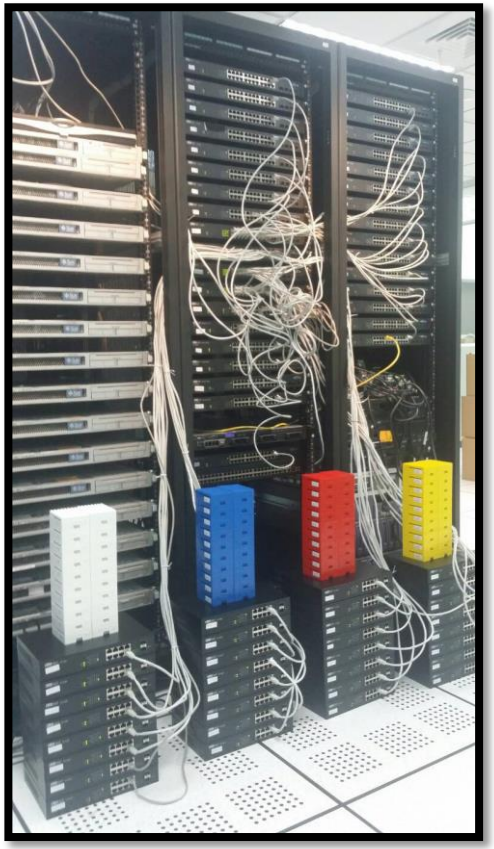
Instruction:
- Meter (Switch IC Based)
- Apply-actions

Matching field:
- Ingress Port
- Physical Port
- MAC SA/DA
- Ether type
- VLAN ID/PCP
- IPv4 SA/DA
- IPv4 DSCP
- IPv4 ECN
- IPv4 Protocol
- TCP Source Port
- TCP Destination Port
- UDP Source Port
- UDP Destination Port
- ICMP type
- ICMP code
- ARP op code

Our Alpha Testbed for 100+ Device Scale

- Comprises 45 Raspberry Pi to build an “IoT Device Access Testbed”
- Every Pi emulates 3-6 IoT device or end hosts. The whole testbed is capable of emulating up to 270+ hosts being simultaneously online.
- Unified control by a central script, allowing quick launch of experiments

Our Beta Testbed for 100,00+ IoT Devices



- Located in Si-Soft Research Center, Hsinchu Science Park.
- 84-100 real RT188T switch, which uses Realtek's 838 series IC.
- 4 high-speed servers, emulating 40 virtual switches being online.
- 100 Raspberry Pi emulating 100,00+ IoT devices
- **Capability: emulating a large network composed of 100 switches, connected with 10,000 IoT devices**

Problem of Testing with Real-world Testbed

- Complexity of Deployment
  - Deployment usually requires 1-2 engineers to work half-to-one day.
- Complexity of Launching Script
  - Requires 1 engineer to spend one day to write and test the start script
- Complexity of Changes
  - Difficult to change → So, we don't change it!

In the past, we used "mininet" to do pre-testbed test.

What we learned from VT-Mininet

This inspired us!

What do we want?

Container → clean and convenience name space isolation

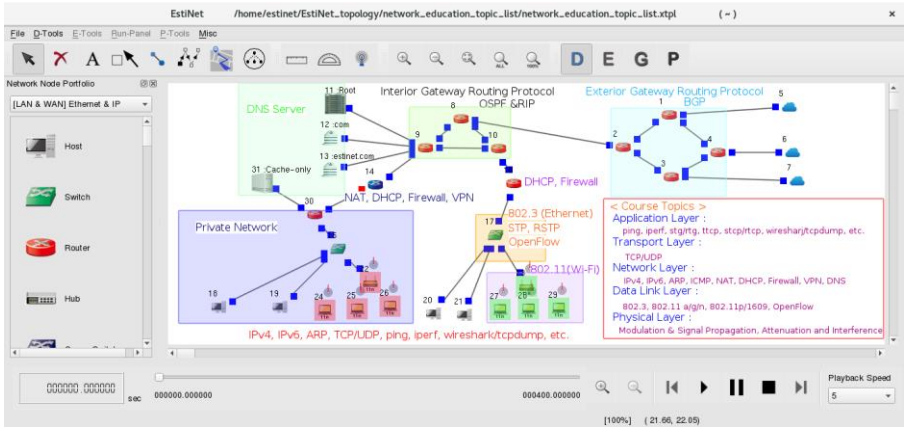
test real-life programs

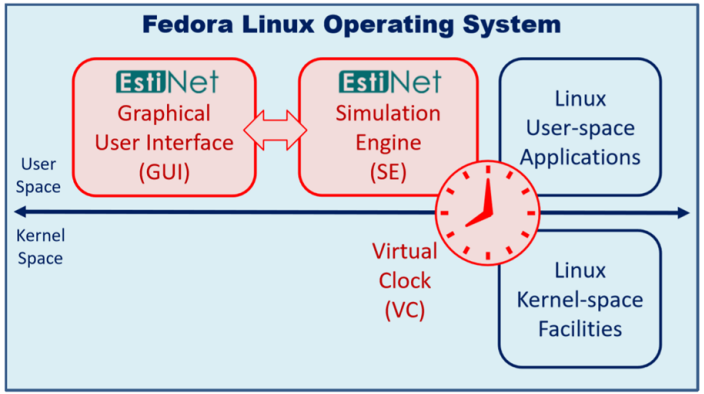
No try-and-error for time dilation setting → adaptive virtual time control

OUR WORK IN 2019

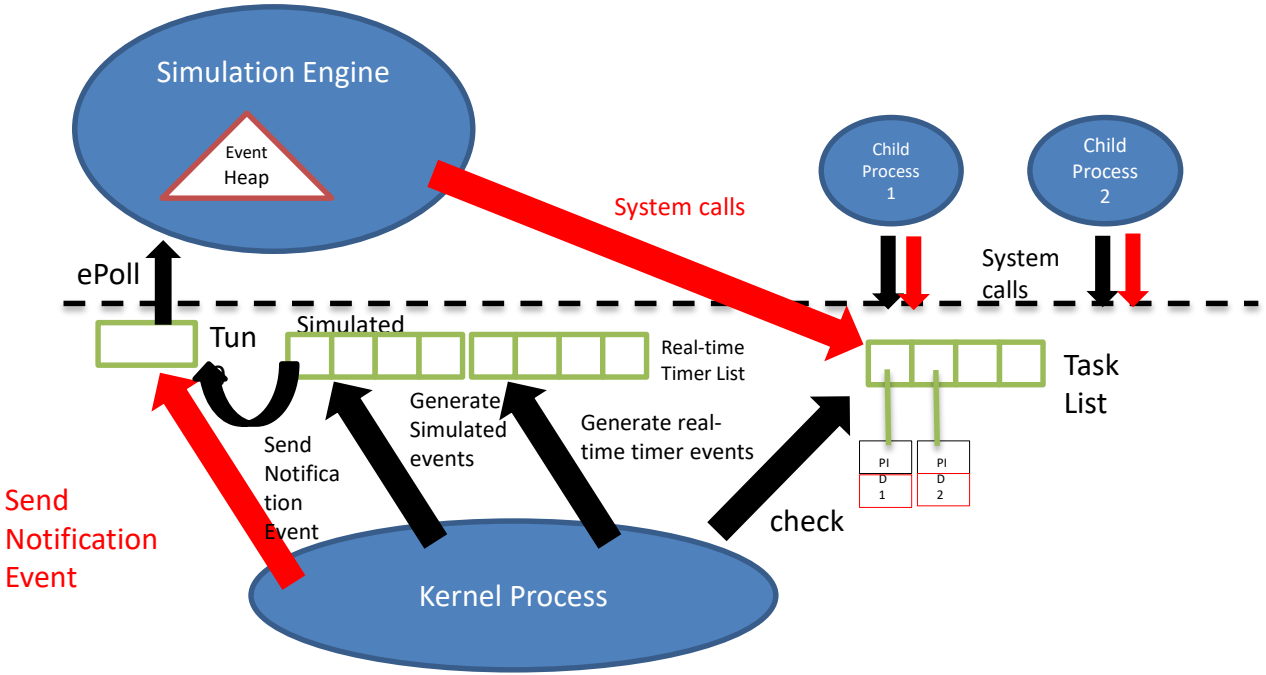
We Modified EstiNet Network Simulator to Achieve This!

- Formally named as NCTUns (National Chiao Tung Univ. network simulator, http://nsl.cs.nctu.edu.tw/NSL/software.html)
- IP-level routing-table manipulation approach to run real-life programs
- Already use the virtual time notion
- Event-driven approach for time advancing → a type of adaptive virtual time control





Patented Approach to Control & Sync System Times of Linux Containers



Modification Summary:

- Process Table
  - A new field denoting the invocation of the IO system calls that may not generate timer events
- Kernel
  - CPU occupation checking logic
  - New notification events for SE
- SE
  - Add a new syscall so that it can check if a child process is calling specific IO system calls.

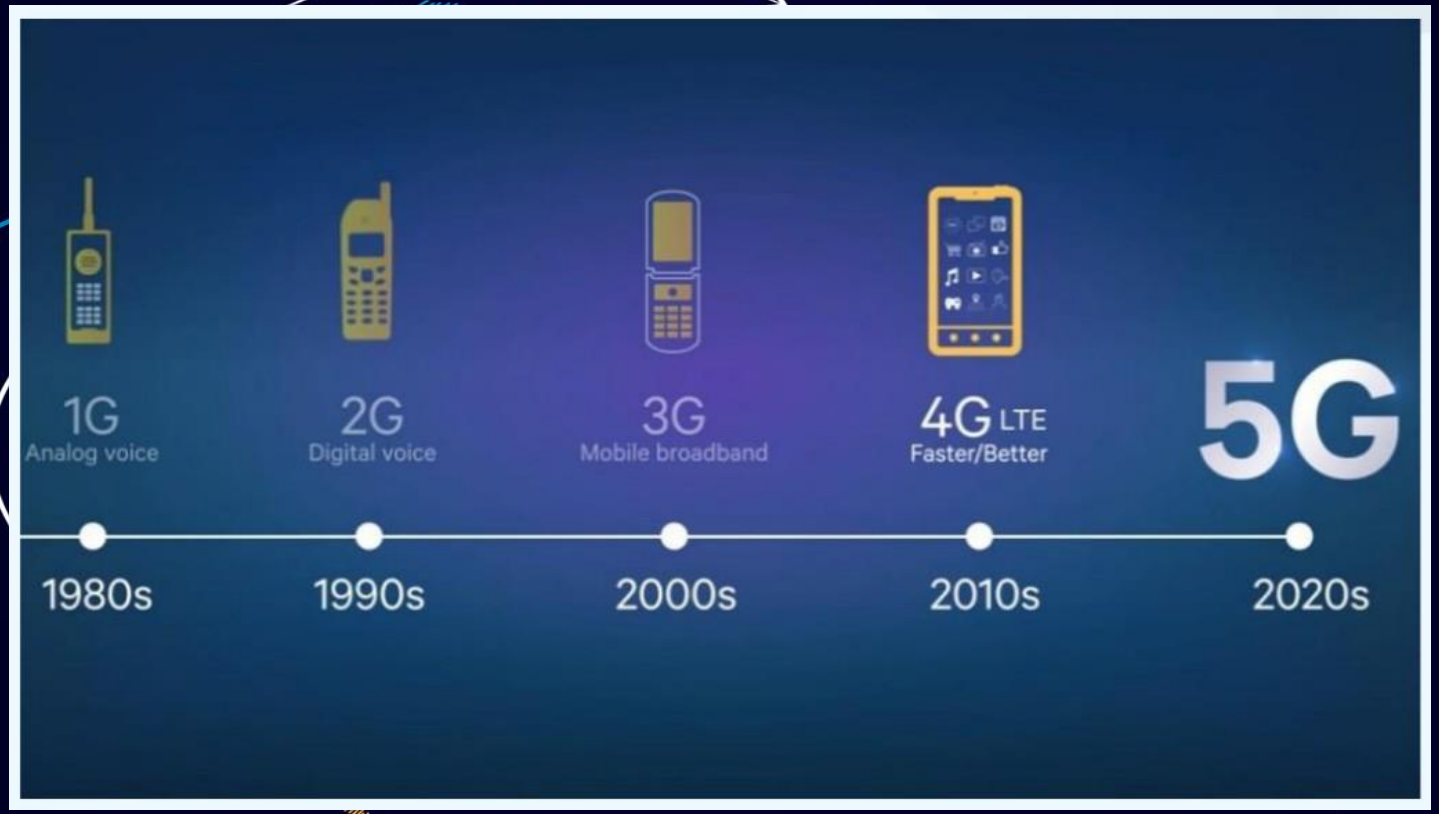
Taiwan Patent: I709308 “網路模擬器平台上之時間控管方法及系統”, 2020/11/01

Comparison among Time Control Methods for Linux Containers

	ASAP Event Scheduling	Loading Monitor	Time Dilation
Rationale	“Event-rized” packets with timestamp sorting and execution	Use a fixed coefficient TDF and check the CPU load to properly shorten the physical elapsed time	Use a fixed coefficient TDF to shorten the physical elapsed time
Software Representatives	EstiNetX	MiniNet-HiFi	VT-MiniNet Diecast SVEET (Event+Time Dilation) SliceTime (NS3+VM, loose time sync.) TimeJails/NETBalance TimeKeeper SELENA (VM-based + Time Dilation)
Download Availability	Yes (Official Website)	Yes (GitHub)	VT-MiniNet (GitHub) Diecast (NA)

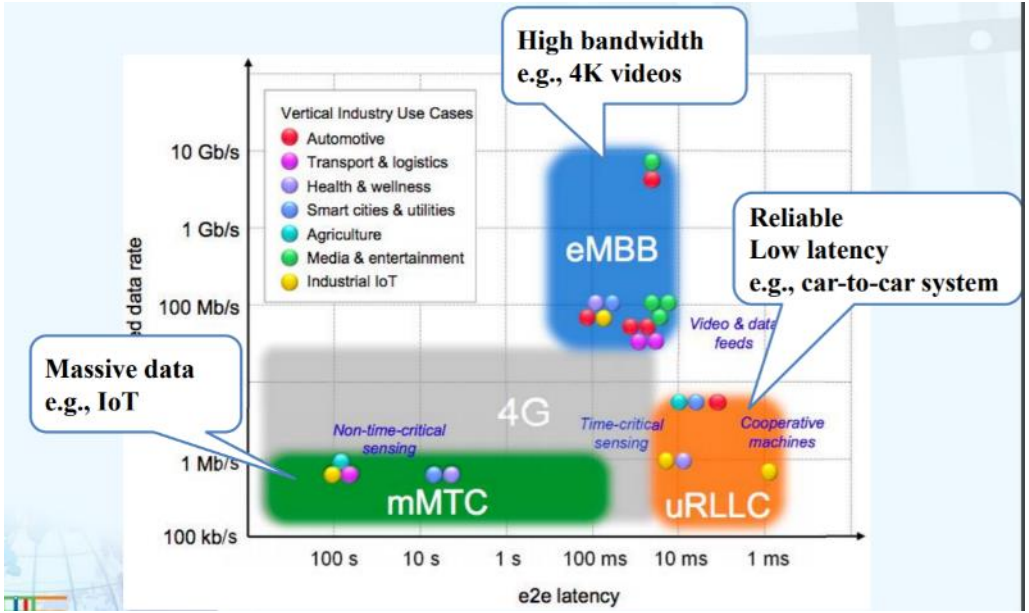
OUR WORK IN 2020

Incoming 5G Era



Source: 陳文村教授，AnNet_2018_Keynote.pdf

Objective of 5G Spec.



- **eMBB: Enhanced Mobile Broadband**
  - Downlink: 20Gbps
  - Uplink: 10Gbps
- **URLLC: Ultra-reliable and Low Latency Communications**
  - Control-plane Latency: 10ms
  - Data-plane Latency: 0.5ms
  - Mobility unavailability: 0ms
  - Reliability: 99.999%
- **mMTC: massive Machine Type Communications**
  - 106 device/km^2 (under certain QoS req.)

Source: 陳文村教授，AnNet_2018_Keynote.pdf

5G Network Architecture

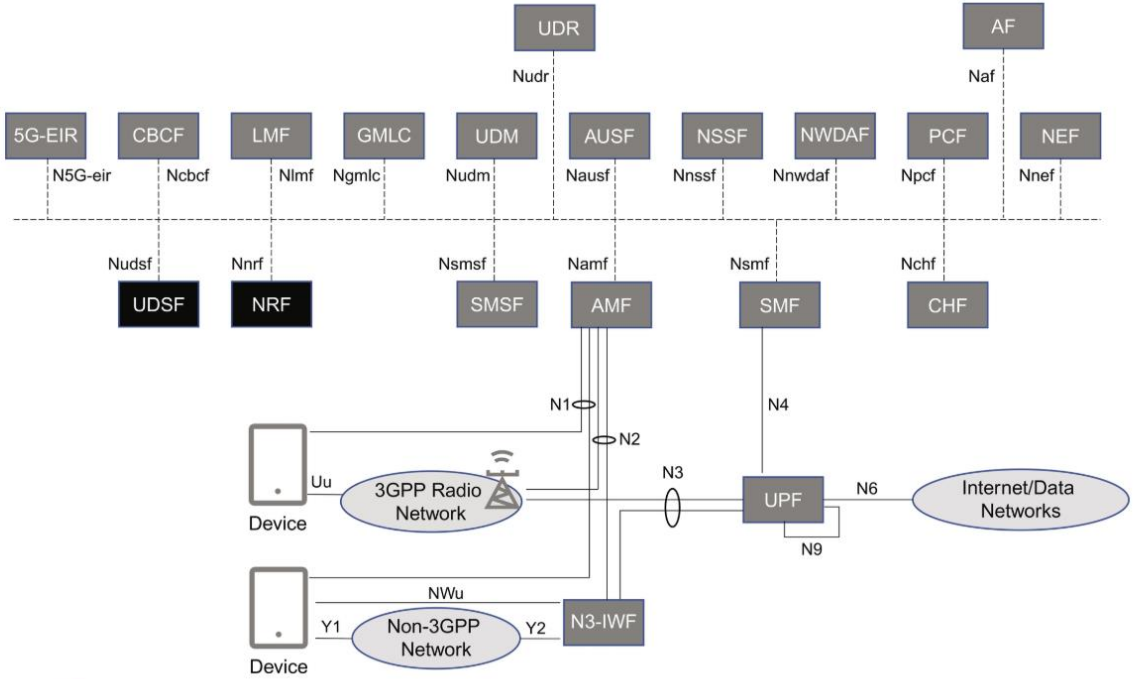


FIG. 3.3 5G Core architecture visualized with Service-Based interfaces.

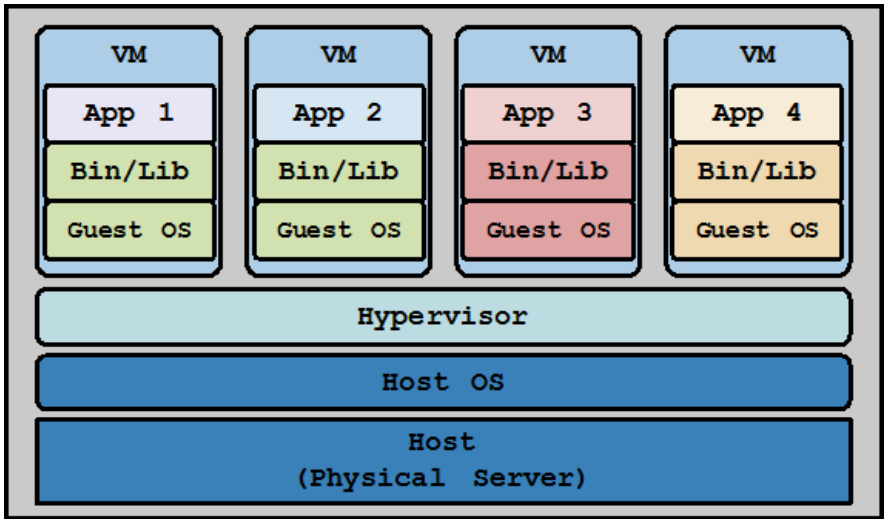
New Architecture of 5G Core:

- Micro-Service
- Service-based Interface
  - Realize Service Function Chain in SDN
  - HTTP RESTFUL System
    - REST (Representational State Transfer)

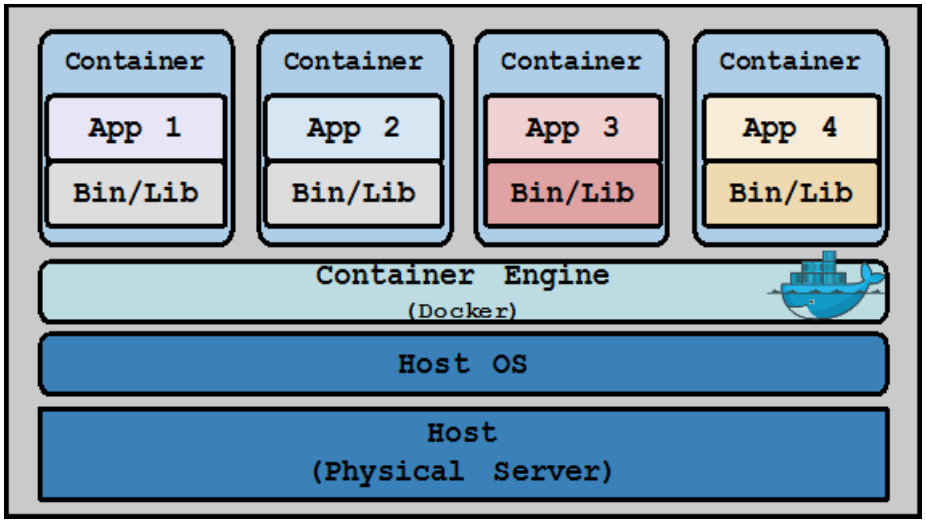
Source: Stefan Rommer, "5G Core Networks"


CONTAINER-BASED
5G SIMULATION PLATFORM

Difference Between Container and VM



VM Architecture



Container Architecture

Introduction to Free5GC

free5GC

Members

Platinum

Chunghwa Telecom

FUJITSU

ONF
Open Networking Foundation

WNC
Wistron NeWeb Corp.

Silver

EstiNet

- Developed by Prof. Jyh-Cheng Chen, NCTU, Taiwan
- Free to download and use
- Most of source codes are open (a small portion of codes are in binary form)
- Operation with members' fee and supported by Governmental R&D projects

Free5GC Stage-3 Release

Reference Architecture for Stage 2:

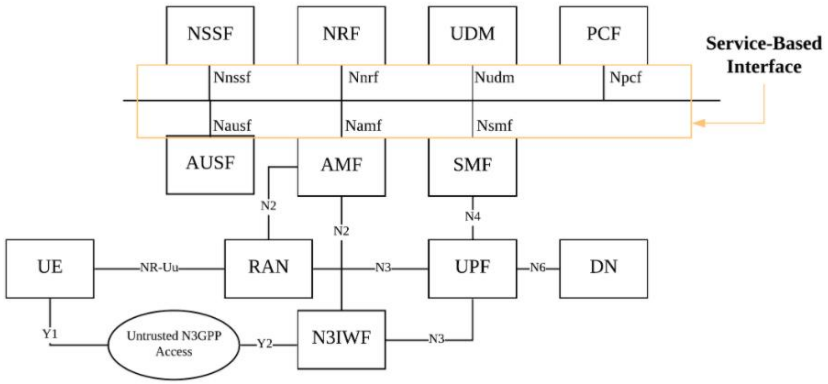
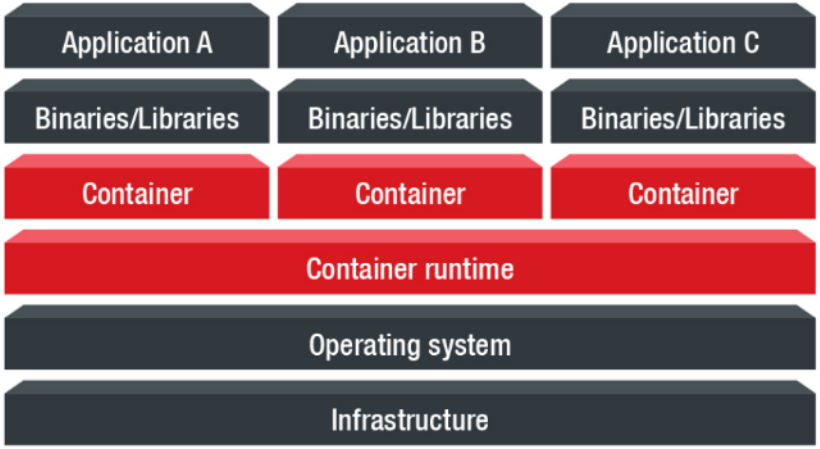


Fig. 2: Stage 2 architecture of free5GC

- Release in April, 2020
- Support Service-based Interface
  - Micro-service
  - Restful HTTP API Arch.
- Support N3IWF function

Concept of Container

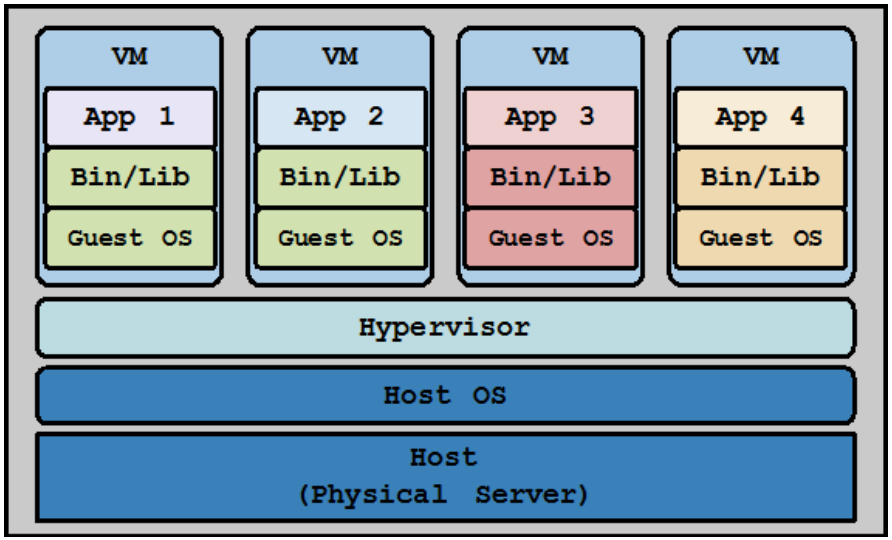


- Conceptually isolated unit for a group of software package
  - Application
  - Library
  - CPU+MEM+Storage+Network
- Linux **namespace** technology
  - CPU namespace
  - Memory namespace
  - Storage namespace
  - Network interface namespace

Source: https://blog.trendmicro.com.tw/?p=60814

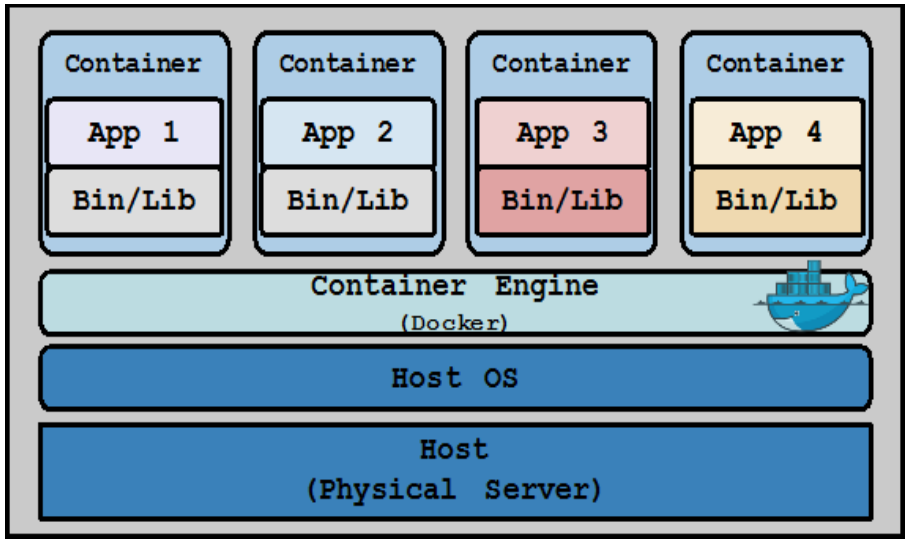
Difference between Container and VM

Translation Approach



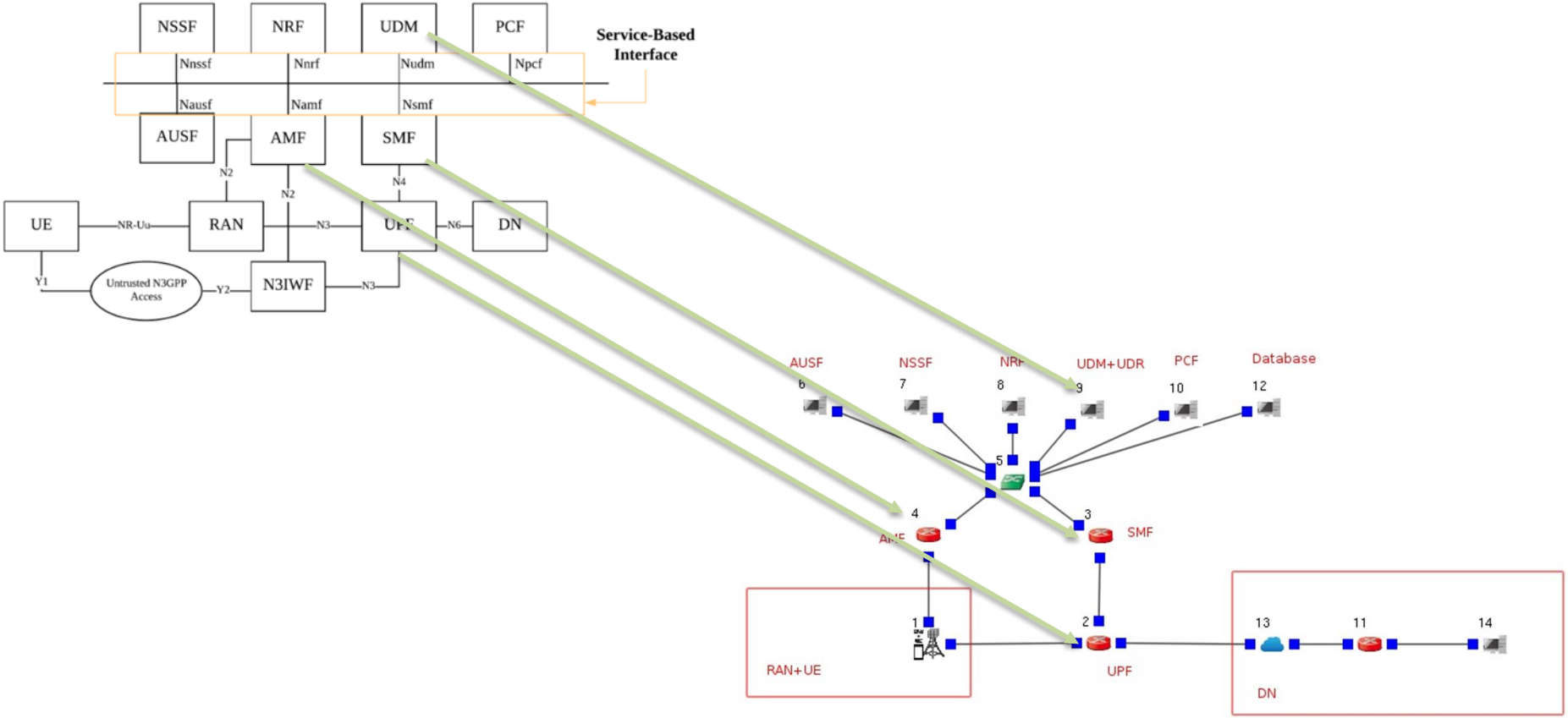
VM Architecture

ID (Data Structure) Approach



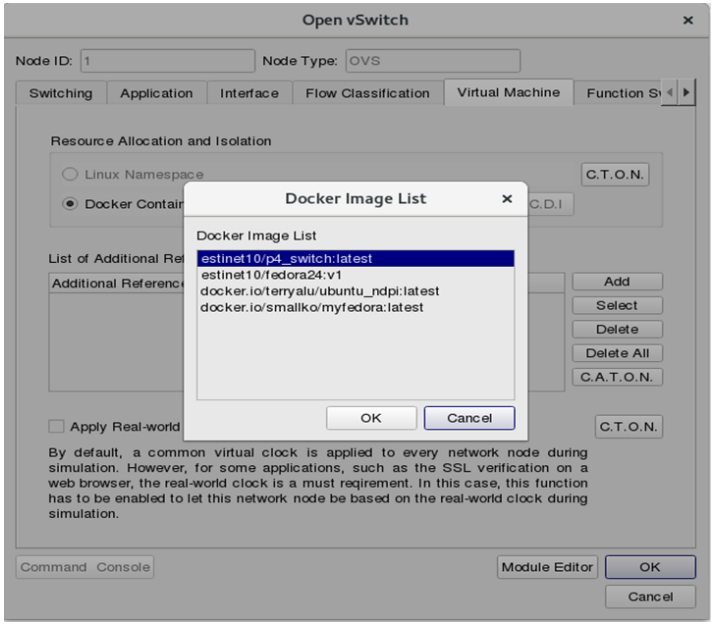
Container Architecture

Micro-service Arch. Fits into Container Technology



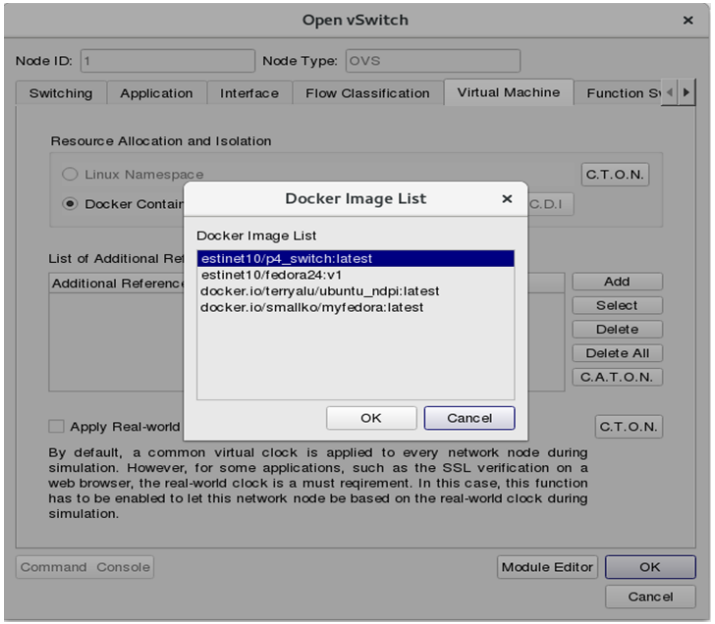
Our Porting Approach

① In our EstiNet11 environment, we created 9 network nodes which are ready to load Docker images.



Our Porting Approach

② We use Free5GC source codes to create a single Docker image which contains all 5GC micro services

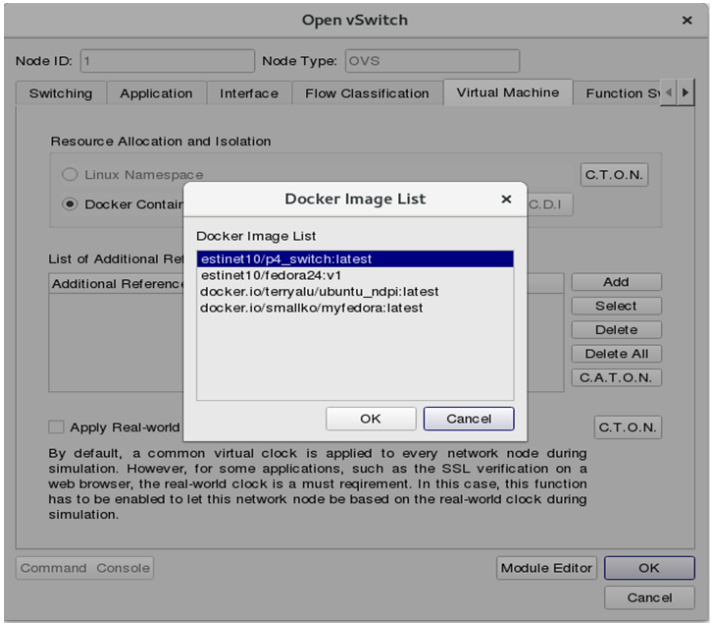


Our Porting Approach

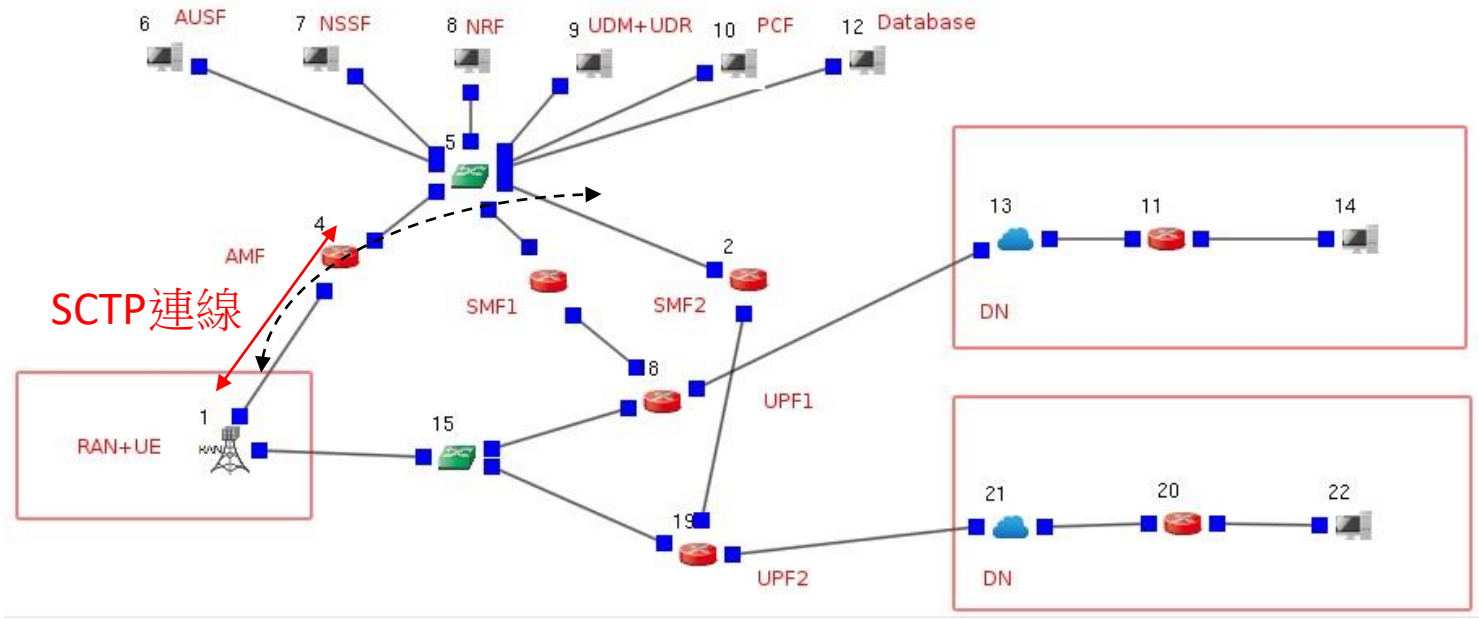
③ Load the Docker image onto each node

④ Configure a specific micro service for each chosen node

- e.g., the AMF node runs the AMF micro service on its starting script
- Follow the same way that one runs Free5GC in the real world

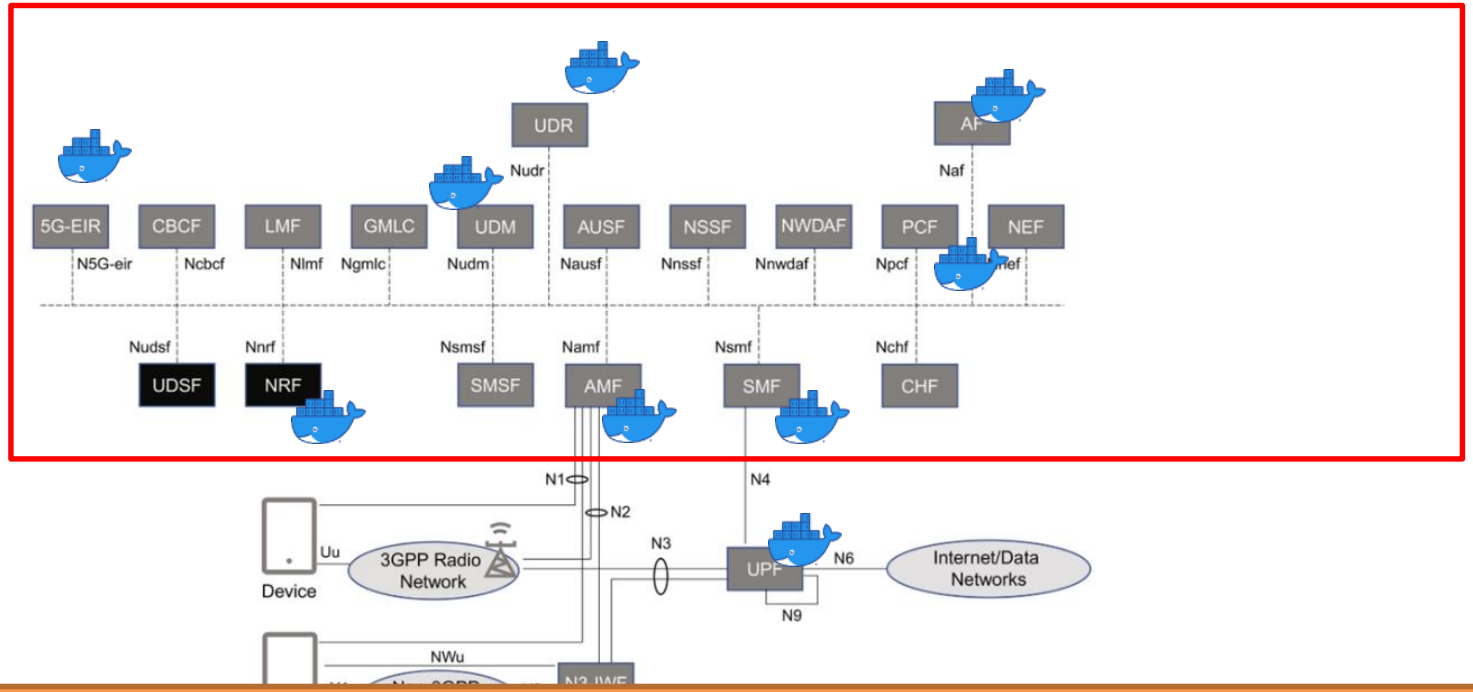


Modifications to Free5GC v3.0.3



- **In our environment, we change to the type of the micro service process to “Real-time Process” in Linux kernel.**
- **We change the SCTP connections used in Free5GC from non-blocking mode back to blocking mode, in order to prevent AMF from occupying too much CPU resource. This will cause the issue that an UE cannot attach to the network.**
- **Fixed the issue that SMF always returns the same Network Slicing ID.**

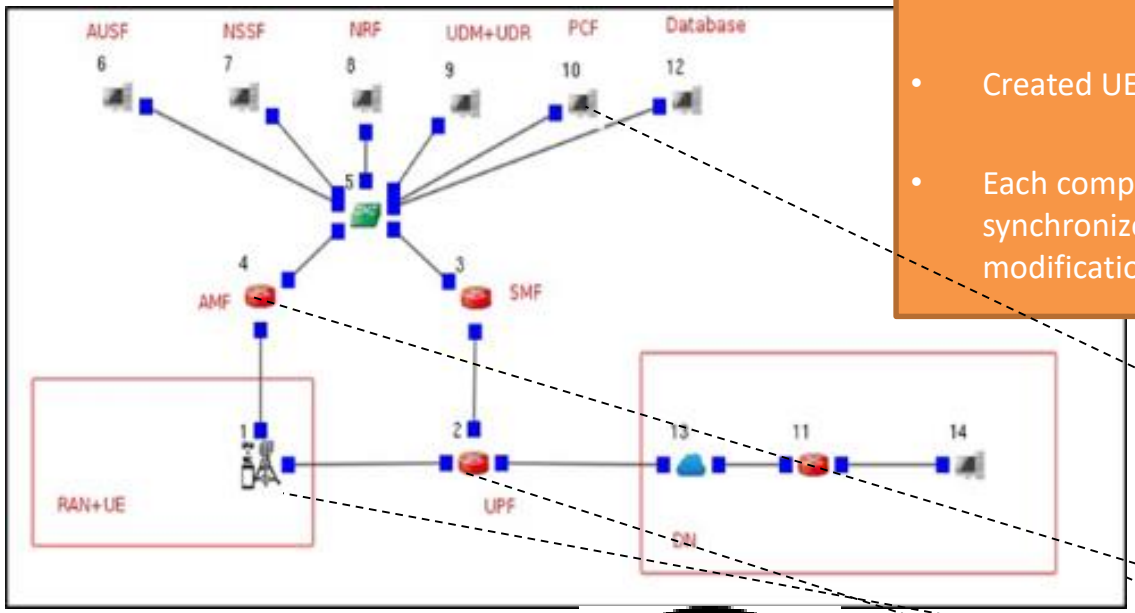
5GC Micro-service Architecture on Containers

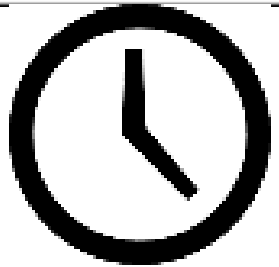


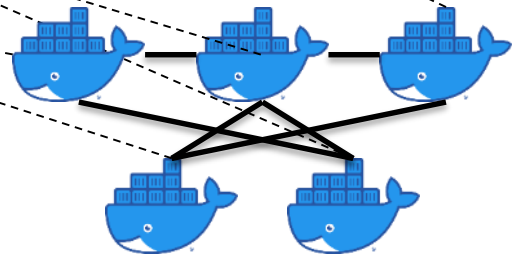
All micro-services of 5GC on one machine is realized by the Linux Container Technology.
Next Question: How to achieve repeatable results and to do observations?

A Result-repeatable 5G Network Platform by Software

- Have done the 5GC part some patches
- Created UE+RAN simplified implementation
- Each component is run by a container and time synchronized/controlled by the patented SE and kernel modifications

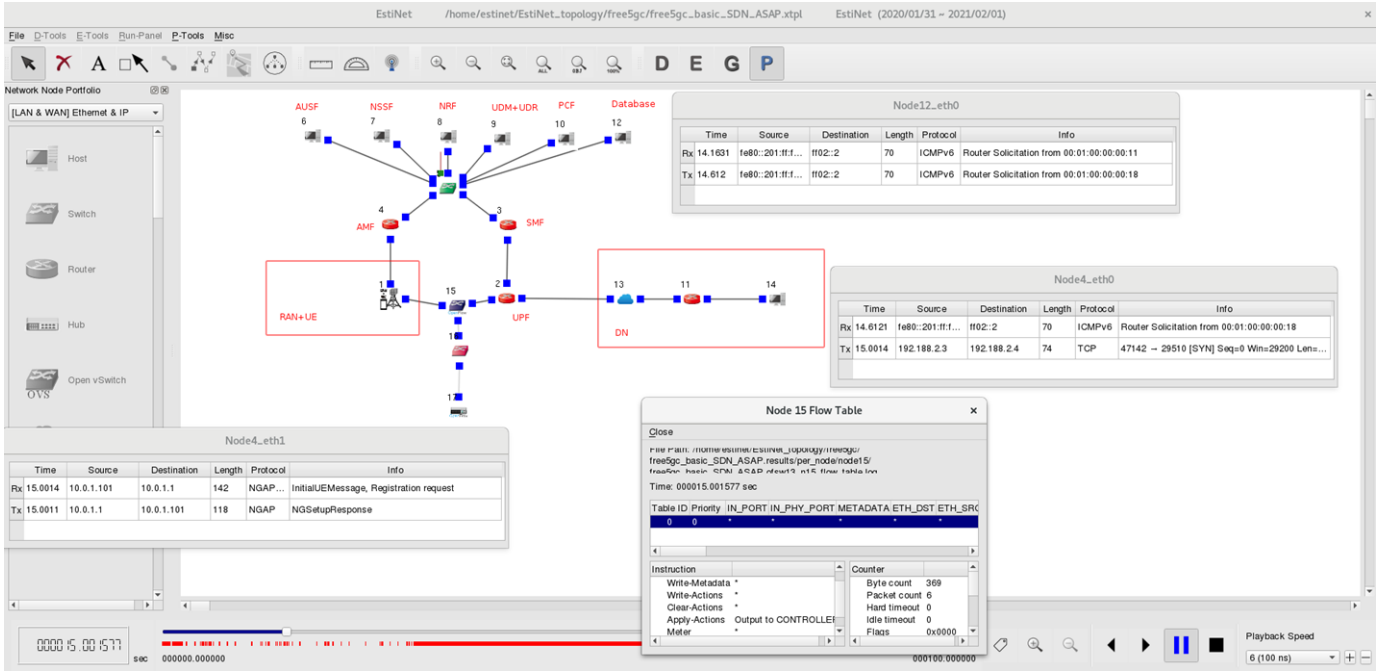






Video Demo

- Run a 5G network simulation with Free5GC and synchronized multiple visual packet analyzers



User List of This Platform

Taiwan

- National ChiaoTung University
- National Sun Yat-sen University
- National Taipei University of Education
- National Yunlin University of Science and Technology
- National Kaoshung University of Science and Technology
- FuJen Catholic University
- National Formosa University
- TungHai University
- ChaoYang University of Technology

Overseas

- India
  - IIT Bhubaneswar
  - Manipal University, Jaipur
- France
  - Université Paris-Est Créteil (UPEC, Paris 12th Univ.)
- Slovak
  - Slovak University of Technology in Bratislava
- China
  - BeiJing JiaoTong University
  - ChongQing JiaoTong University
  - XiDian University
  - GuiLin University of Aerospace Technology

Thanks very much for your listening!

Q&A Time