

오픈소스 기반 Telco Cloud

v1.0

JS Lab

2021년 8월 30일

안종석

james@jslab.kr

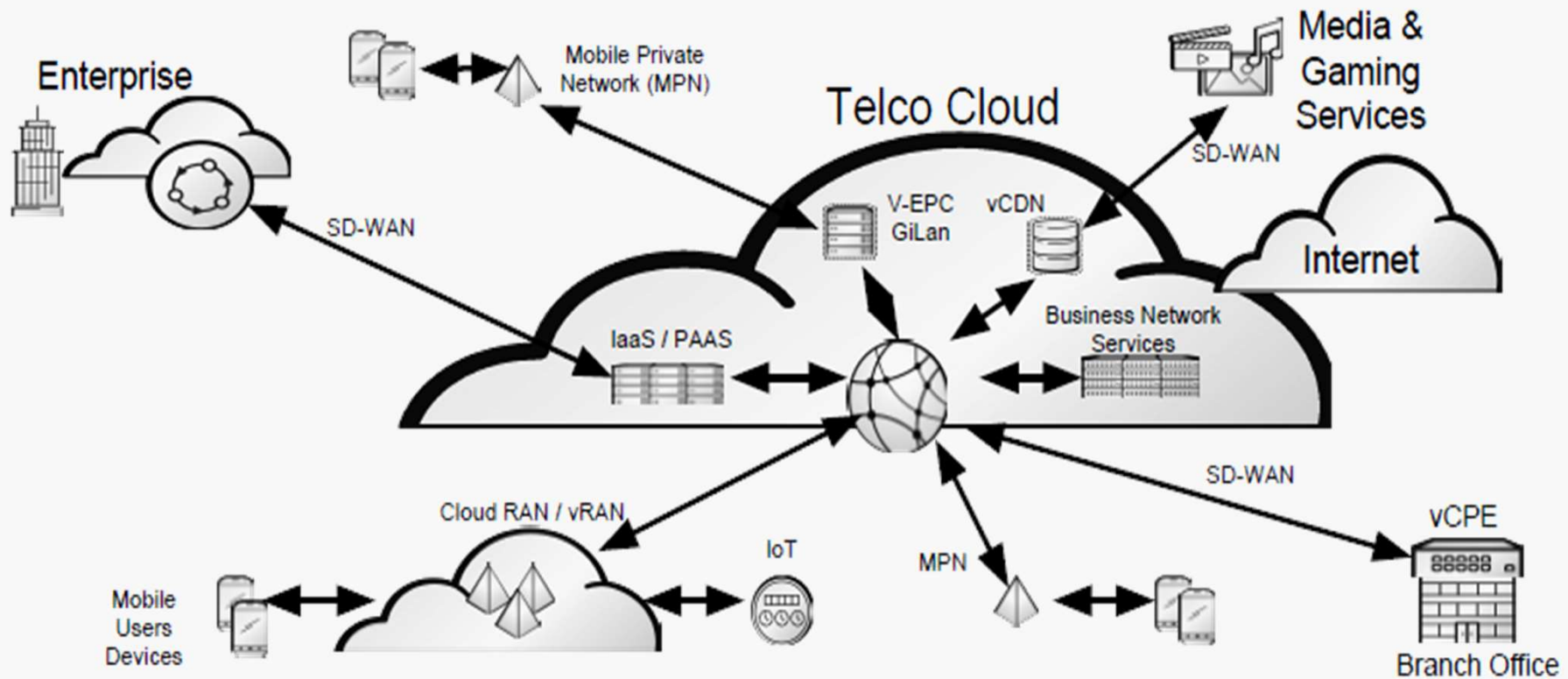
I. 텔코(Telco) 클라우드	3
II. 오픈소스 프로젝트	19
III. 응용 기술	35
IV. 기업을 위한 Telco Cloud	66

I. 텔코(Telco) 클라우드

- 텔코(Telco) 클라우드
- 5G 코어 인프라 기반 NFV의 클라우드화
- PNF/VNF/CNF
- Technology strategy
- 5G Super Blueprint
- 클라우드 네이티브 기반 5G 코어 아키텍처
- 서비스메시(Service Mesh)
- 오픈소스 수용 제조사의 Telco Cloud 정책
- 5G Network-in-a-Box
- 오픈소스 RAN/CN 소프트웨어
- KVM 상에 free5GC 설치 환경
- 오픈 프레임워크와 프로젝트
- ONF 프레임워크 관계

I. 텔코(Telco) 클라우드

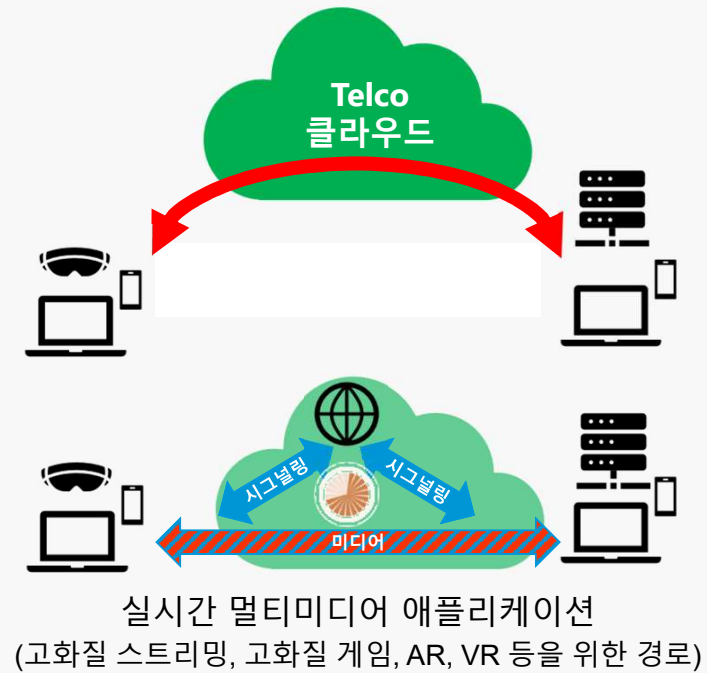
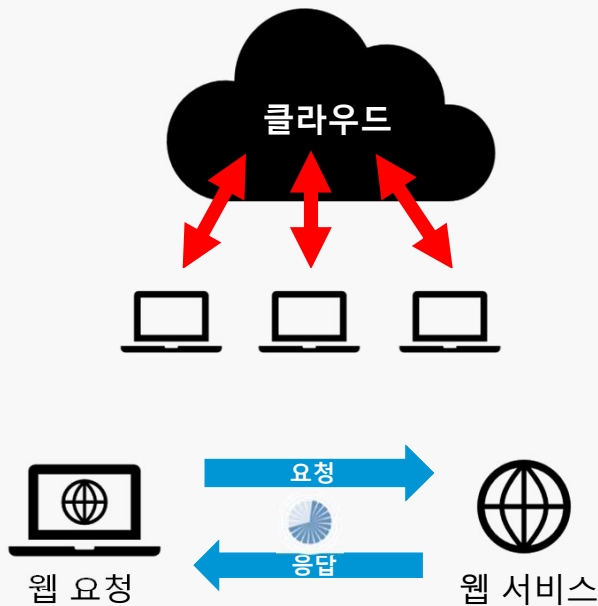
- 텔코(Telco) 클라우드: 텔코 인프라에서 클라우드 기술 적용



I. 텔코(Telco) 클라우드

□ 5G 코어 인프라 기반 NFV의 클라우드화

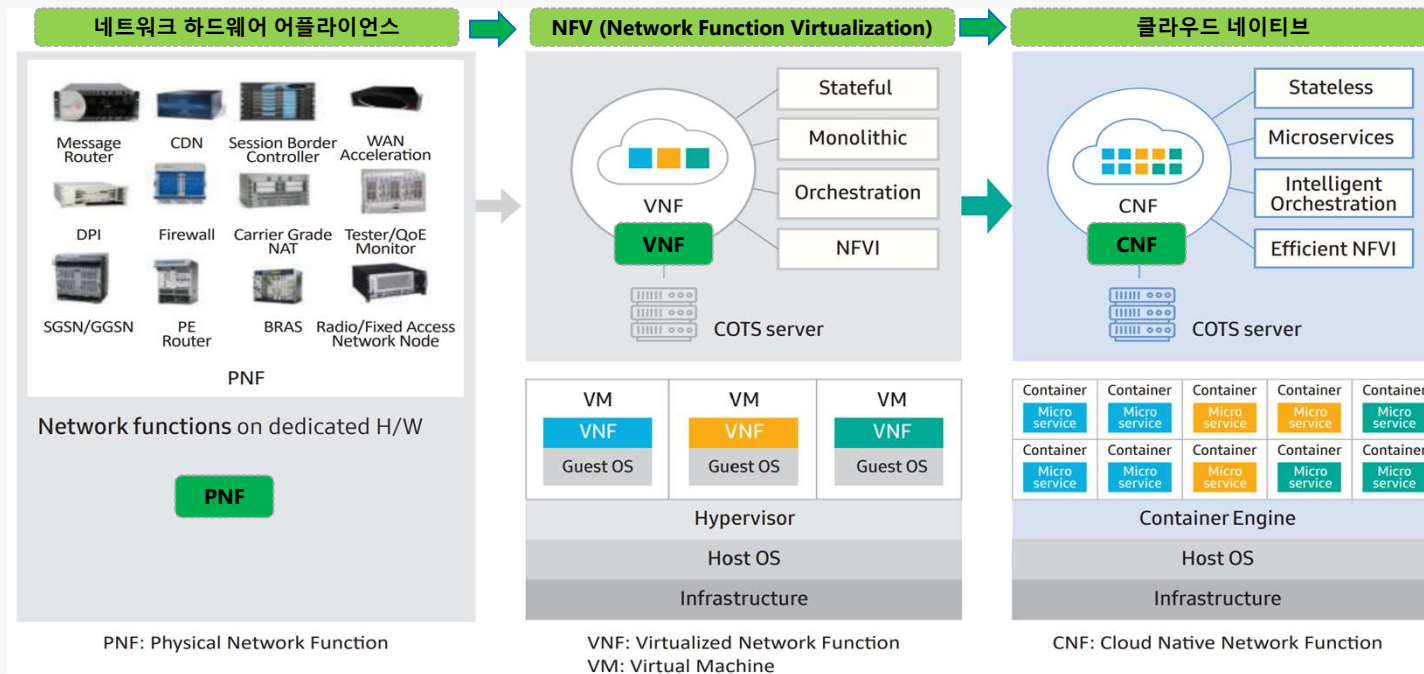
- Public Cloud: 소프트웨어 정의 가상 인프라 기반 서비스 (웹서비스)
- Telco Cloud: 언더레이 인프라 기반 클라우드 서비스 (전송경로 제공)
- Telco Cloud는 하드웨어 인프라 환경 고려



I. 텔코(Telco) 클라우드

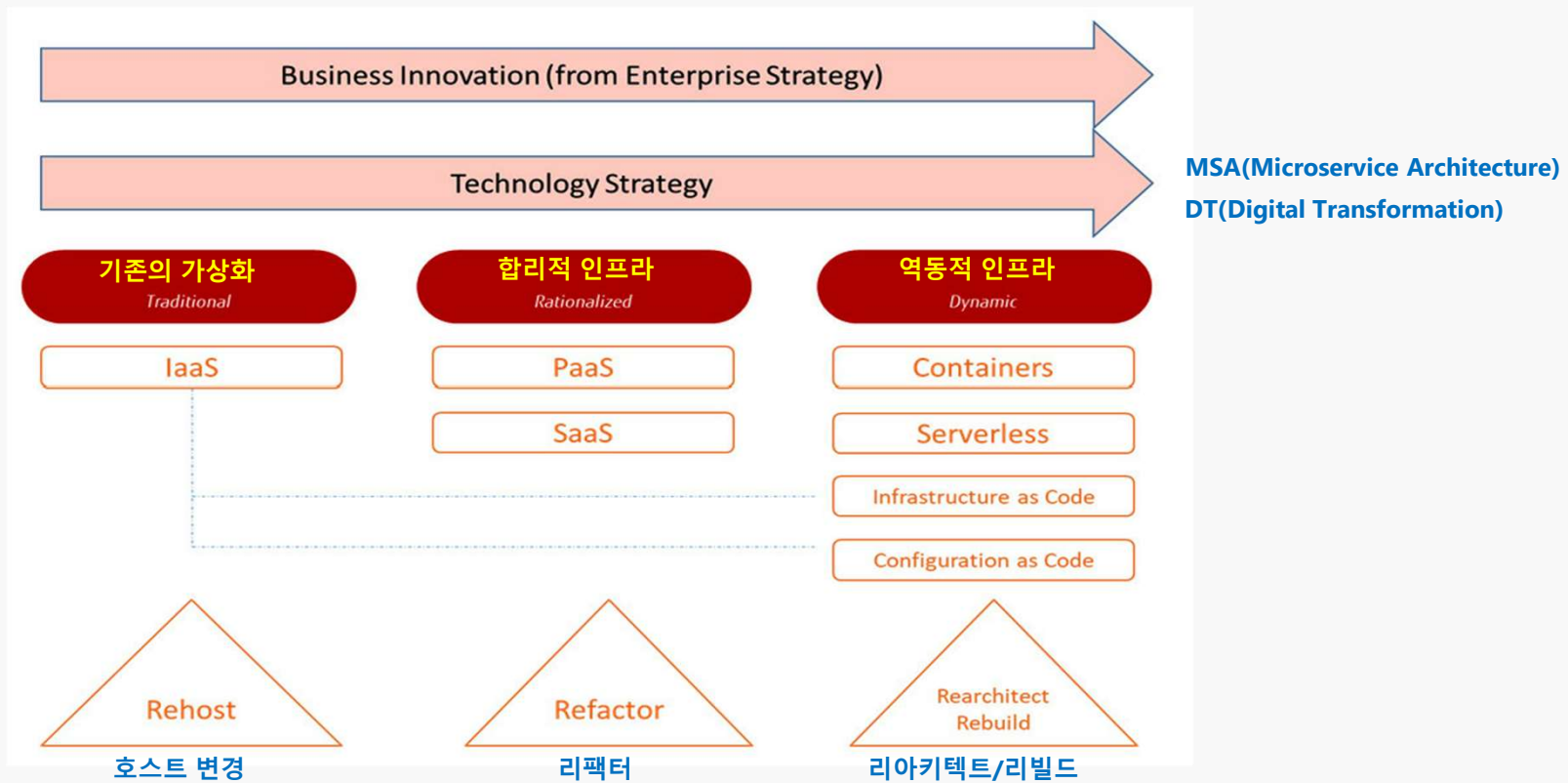
- ❑ PNF (Physical Network Function): 하드웨어 어플라이언스 기반
- ❑ VNF (Virtualized Network Function): 가상머신 VM(Virtual Machine) 기반
- ❑ CNF (Cloud Native Network Function): 클라우드 네이티브는 컨테이너 기반, VM 등을 수용

5G 코어는 클라우드 네이티브로 진화 중 (Evolving to Cloud Native)



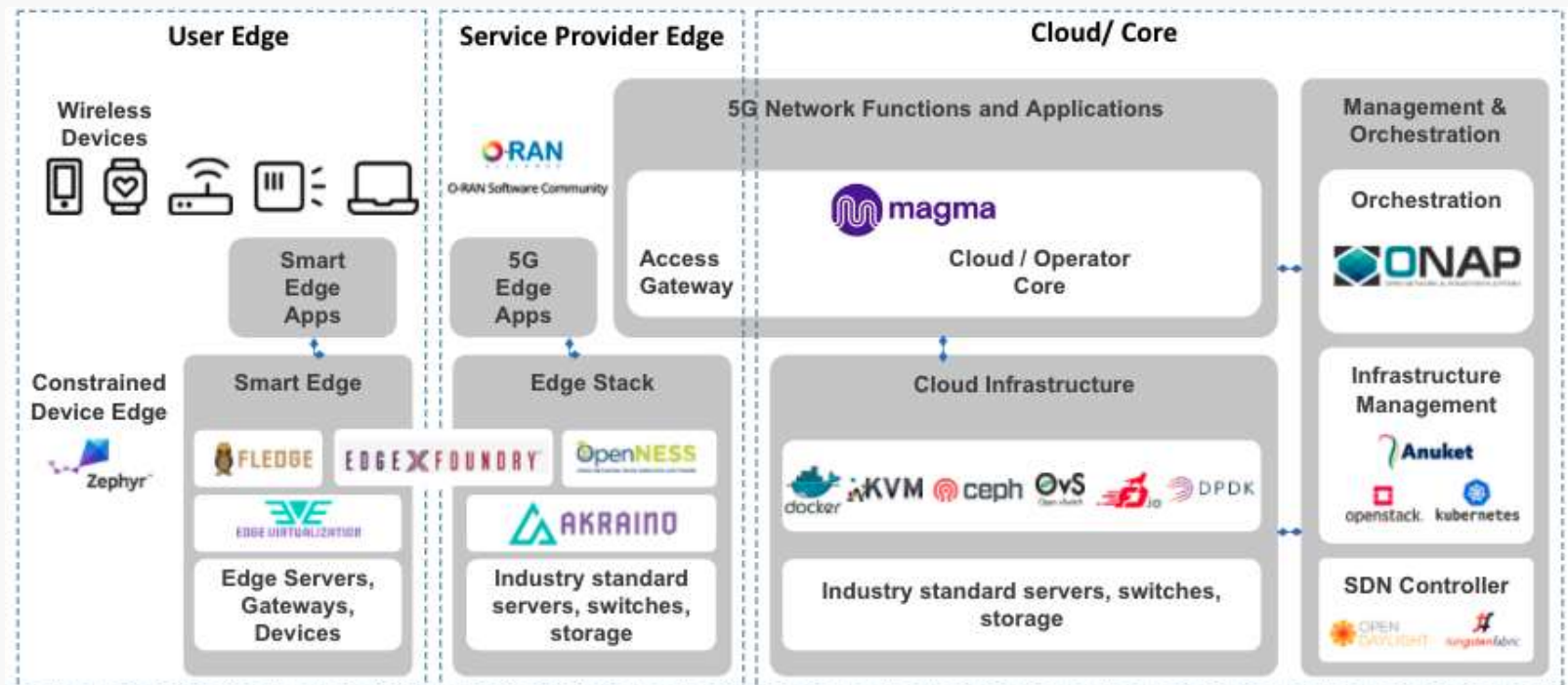
I. 텔코(Telco) 클라우드

- ❑ Technology strategy following business innovation
- ❑ 시험적 Refactor 포함 (엔터프라이즈)



I. 텔코(Telco) 클라우드

- 리눅스재단: 5G Super Blueprint
- LF Open Source Component Project for 5G

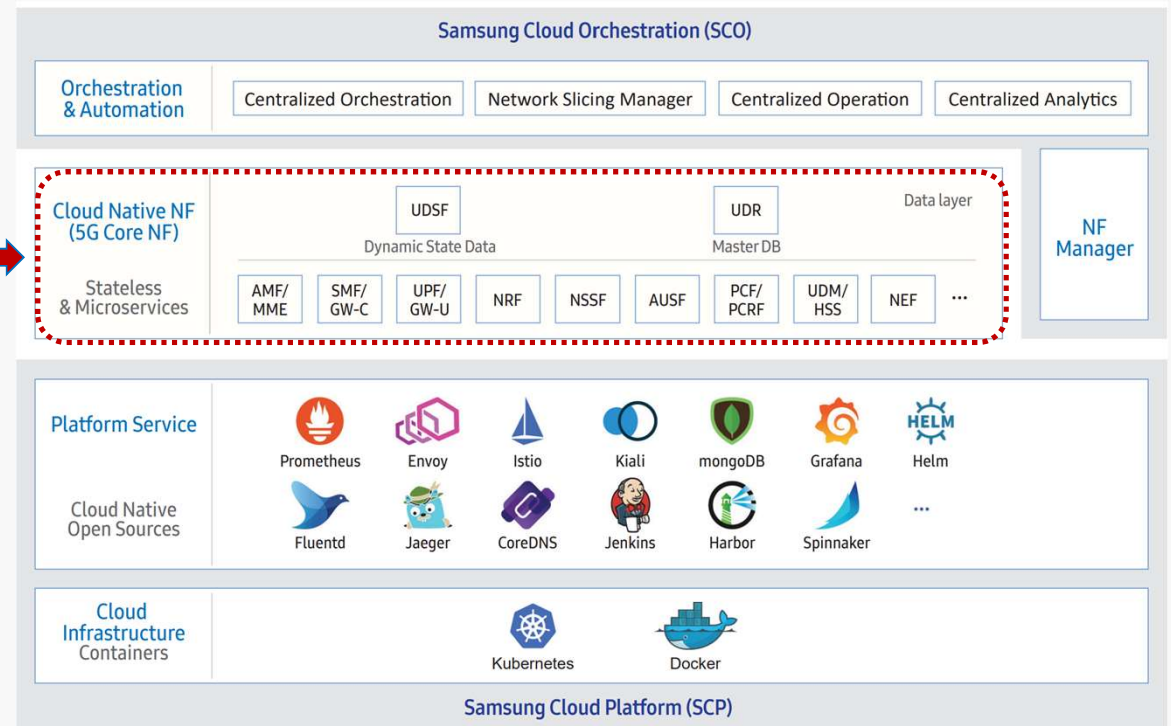


출처: <https://wiki.lfnetworking.org/display/LN/LFN+Demo%3A+5G+Super+Blueprint>

I. 텔코(Telco) 클라우드

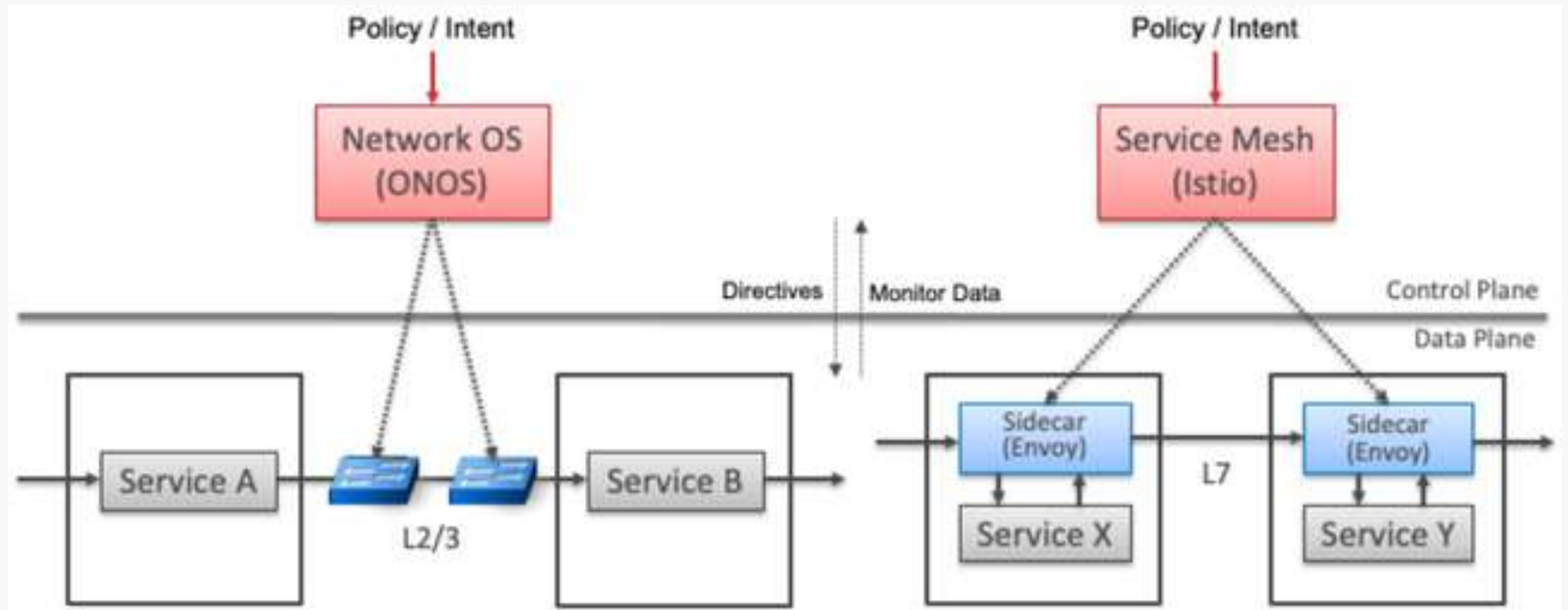
- 클라우드 네이티브 기반 5G 코어 아키텍처
- 레퍼런스: 삼성의 5G Core's Cloud Native Enabled Architecture

구분	Free5GC	Open5GS	OpenAir Interface	srsLTE
언어	Go	C	C, C++	C, C++
플랫폼	self	Docker	self	self
라이선스	Apache V2.0	AGPL V3.0	OAI Public License V1.1	AGPL V3.0
Release 버전	15	16	15	14
기지국 연결	none	UERANSIM	OpenAir Interface	srsLTE



I. 텔코(Telco) 클라우드

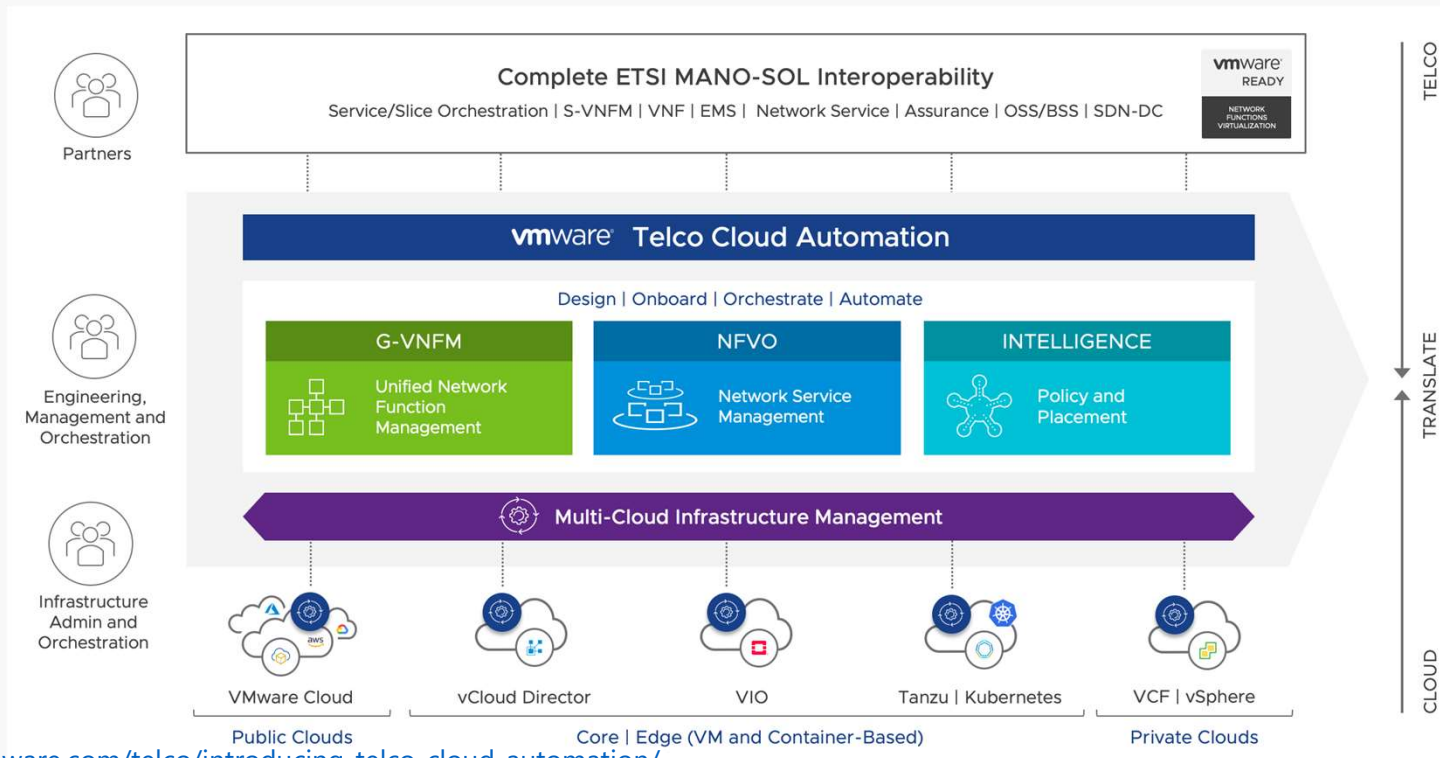
- 클라우드 네이티브의 서비스메시(Service Mesh)
- Service Mesh is just SDN at Layer 7



출처: https://www.theregister.com/2021/06/25/service_mesh_sdn_layer_7/?fbclid=IwAR1PwvdGGBolG8uLvTzbEinPYRoahl-gZIEY_qxwNr9wCJ-U3oqdieYS8Ww

I. 텔코(Telco) 클라우드

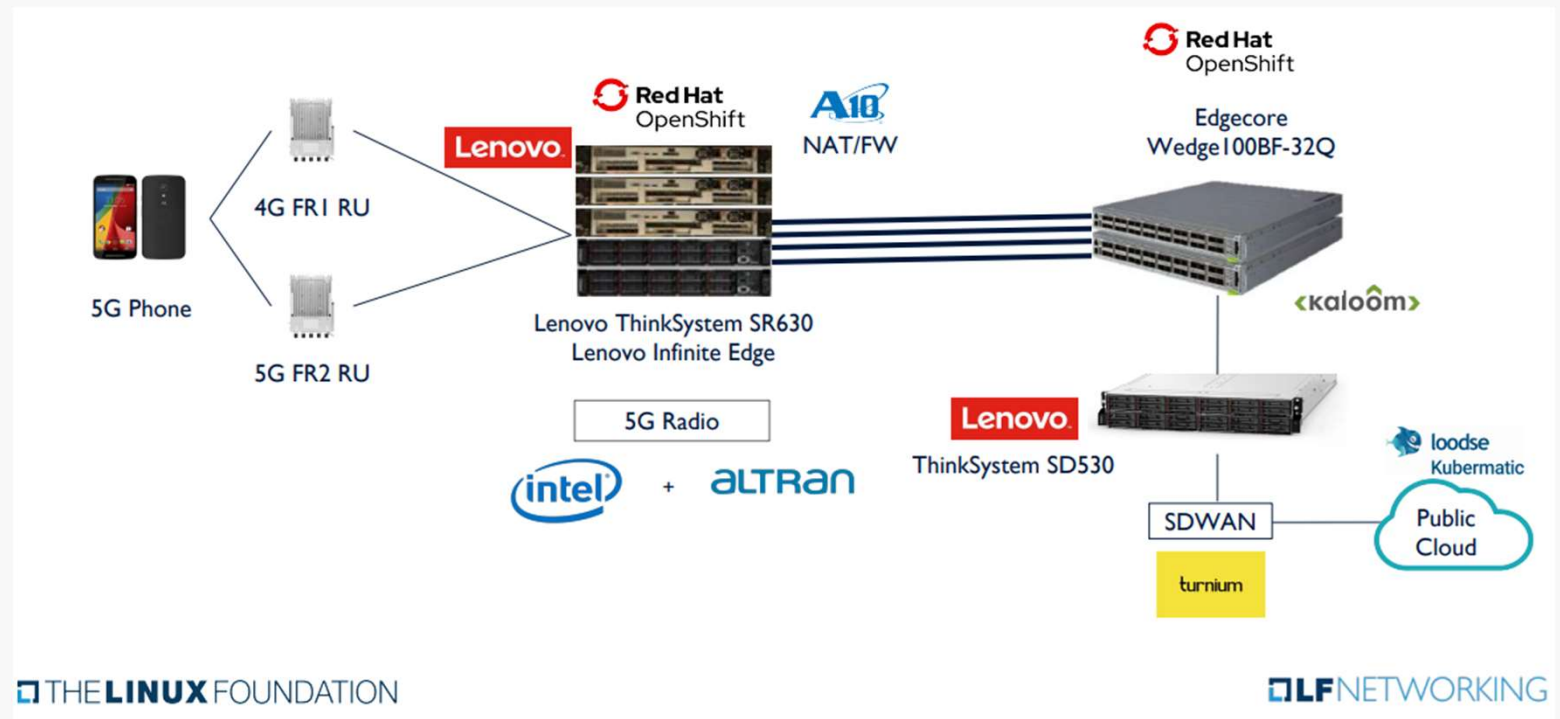
- 오픈소스 수용 제조사의 Telco Cloud 정책 (VMware 예)
 - 오픈스택(OpenStack), 쿠버네티스(Kubernetes) 수용 자동화
 - 오픈소스 기반 파트너 생태계 형성



출처: <https://blogs.vmware.com/telco/introducing-telco-cloud-automation/>

I. 텔코(Telco) 클라우드

- ❑ 제조사의 오픈소스 사용 Cloud Native 5G Demo (예)
- ❑ 5G RAN + Edge Compute

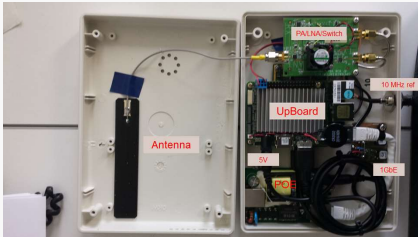


출처: Kuberatic KubeOne: <https://www.kuberatic.com/solutions/5g/>

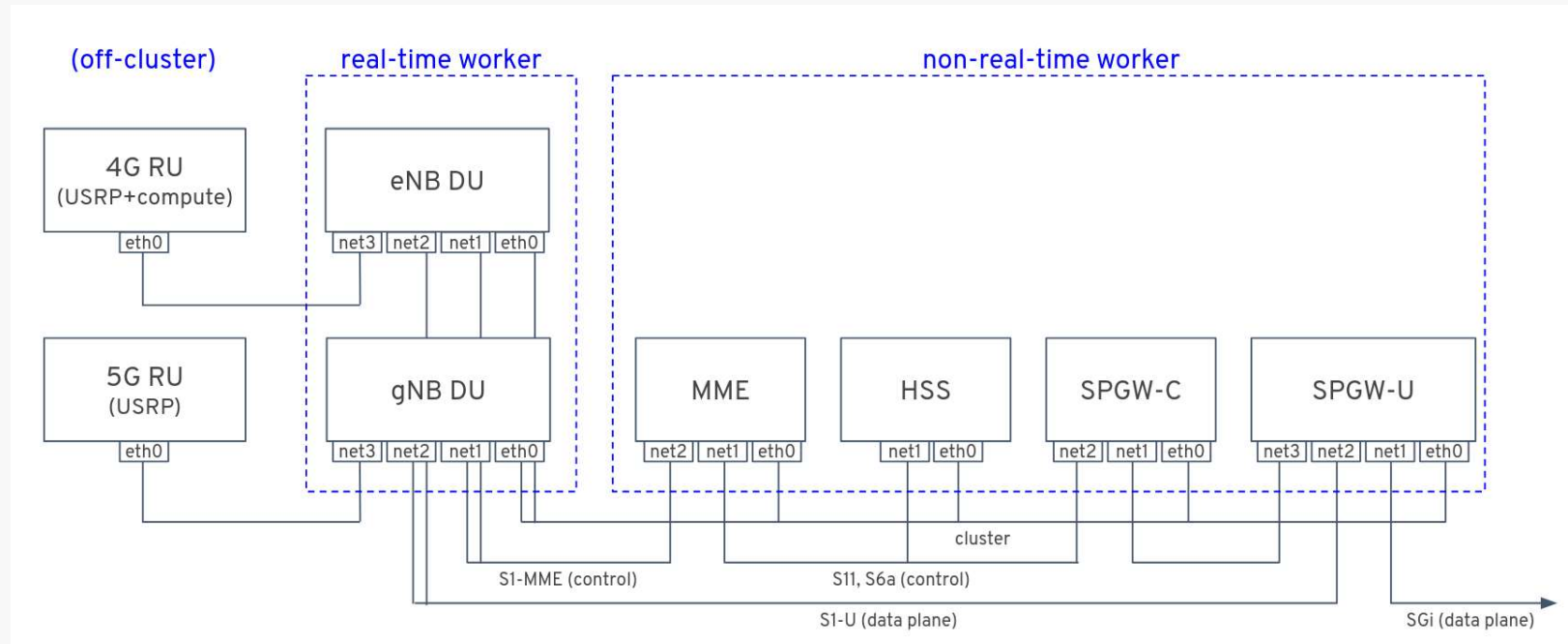
I. 텔코(Telco) 클라우드

❑ Red Hat OpenShift Container Platform

- Real-time worker
- Non-real-time worker



- USRP B200-mini (\$500)
 - Up to 50 MHz BW
- Custom 20 dBm PA/LNA/Switch (\$300)
 - Band 38, 42/43, n38/n77-78
- Upboard/Upboard2
 - (low-end \$90 PC)
- GbE frontHaul POE+
- Antenna

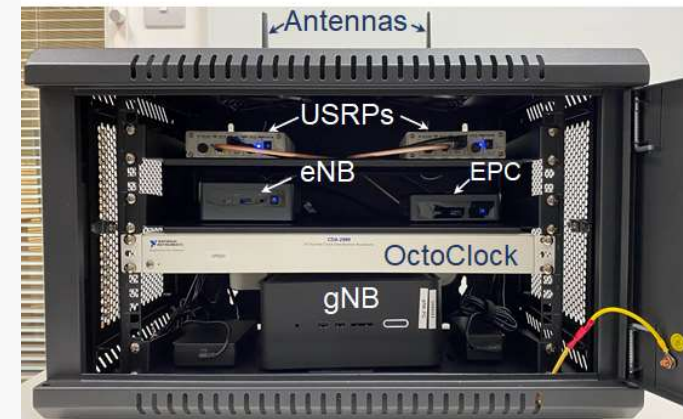
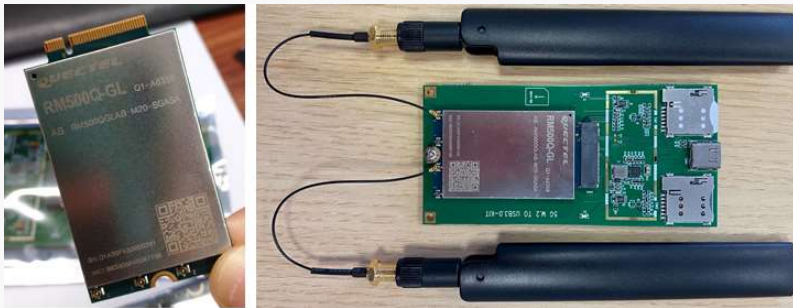


출처: : Red Hat, Deploying a full-service 5G network on OpenShift

I. 텔코(Telco) 클라우드

□ Open and Programmable 5G Network-in-a-Box: Technology Demonstration and Evaluation Results

Quectel's 5G module with M.2 to USB 3.0 adapter and antennas



출처: Adnan Aijaz, Ben Holden, and Fanyu Meng
Bristol Research and Innovation Laboratory, Toshiba Europe Ltd., Bristol, United Kingdom
firstname.lastname@toshiba-bril.com

I. 텔코(Telco) 클라우드

□ 오픈소스 RAN/CN 소프트웨어

오픈소스 RAN 소프트웨어							
RAN 소프트웨어	eNB	gNB	SDR UE	COTS UE 지원	라이선스	Main contributor(s)	커뮤니티 지원
OpenAirInterface	Yes	개발중	가능	Yes	OAI public License v1.1	OAI software alliance, EURECOM	Mailing list
srsLTE	Yes	개발중	가능(불안정)	Yes	GNU AGPLv3	Software radio system	Mailing list
RadisyS	No	Yes, (O-RAN)	No	N/A	Apache v2.0, O-RAN Software License v1.0	RadisyS	No

오픈소스 CN 소프트웨어					
CN 소프트웨어	EPC	gNB	라이선스	Main contributor(s)	커뮤니티 지원
OpenAirInterface	Yes	개발중	Apache v2.0	OpenAirInterface software alliance, EURECOM	Mailing list
srsLTE	Yes	No	GNU AGPLv3	Software radio system	Mailing list
Open5GS	Yes	개발중	GNU AGPLv3	Open5GS	Mailing list
OMEC	Yes	호환	Apache v2.0	ONF, Intel, Deutsche Telekom, Sprint, AT&T	Mailing list
free5GC	No	Yes	Apache v2.0	Free5GC	No

출처: Survey paper, Computer Networks 182 (2020) 107516
 Open, Programmable, and Virtualized 5G Networks: State-of-the-Art and the Road Ahead☆
 Leonardo Bonati *, Michele Polese, Salvatore D'Oro, Stefano Basagni, Tommaso Melodia
 Institute for the Wireless Internet of Things, Northeastern University, Boston, MA 02115, USA

I. 텔코(Telco) 클라우드

□ KVM 상에 free5GC 설치 환경 (예)

□ Software

- OS: Ubuntu 18.04
- Linux kernel: 4.15.0-43-generic
- gcc 7.3.0
- Go 1.11.4
- QEMU emulator 2.11.1

□ Minimum Hardware

- CPU: Intel i5 processor
- RAM: 4GB
- Hard drive: 160G
- NIC card: 1Gbps ethernet card

□ Hardware Tested

- eNB
- WNC OSQ4G-01E2, 3GPP Rel-13 compliance (4G LTE Small Cell)
- D-Link DWR-1012, 3GPP Rel-12 compliance (4G LTE Small Cell)
- GemTek WLTGFC-101, 3GPP Rel-9 compliance (4G LTE Small Cell)

□ UE

- LG C90 cellular phone
- D-Link DWR-932C dongle via USB cab

출처: free5GC

I. 텔코(Telco) 클라우드

□ 오픈 프레임워크와 프로젝트

모바일 (Mobile)					
프레임워크	집중분야	상태	라이선스	Main 멤버	커뮤니티 지원
O-RAN	Virtualized, intelligent RAN	가능	Apache v2.0, O-RAN software license v1.0	O-RAN Alliance w/telecom operators	No
COMAC	Agile service delivery at the edge	가능	Apache v2.0	ONF	Mailing list
SD-RAN	CU/DU control and user planes	개발중		ONF	N/A
Aether	5G/LTE, Edge-Cloud-as-a-Service(ECaaS)	개발중		ONF	N/A
Magma	CN Orchestration	가능	BSD	페이스북	Mailing list/forum
OpenRAN	Programmable, disaggregated RAN w/open interfaces	소스 비공개		TIP	No
Radio Edge Cloud	O-RAN RIC automated configuration/integration testing blueprint	가능	Apache v2.0	Akraino	No
Aerial	SDK for GPU-accelerated 5G vRAN	Early access	proprietary	NVIDIA	N/A

슬라이싱 (Slicing)					
프레임워크	집중분야	상태	라이선스	Main 멤버	커뮤니티 지원
5G-EmPOWER	Centralized controlled for heterogeneous RAN	가능	Apache v2.0	FBK (in the framework of multiple EU projects)	N/A
FlexRAN	Real-time controller for software-defined RAN	가능	MIT License	Mosaic5G Consortium	Mailing list

에지 (Edge)					
프레임워크	집중분야	상태	라이선스	Main 멤버	커뮤니티 지원
CORD (Central Office Re-architected as a Datacenter)	Data center for network edge	가능	Apache v2.0	ONF, AT&T, Google, Telefonica	Mailing list
LL-MEC	Low-latency MEC and network slicing	가능	Apache v2.0	Mosaic5G Consortium	Mailing list
LightEdge	MEC services	가능	Apache v2.0	FBK (in the framework of multiple EU projects)	N/A

I. 텔코(Telco) 클라우드

□ ONF 프레임워크 관계

- COMAC (Converged Multi-Access and Core)
- CORD (Central Office Re-architected as a Datacenter)
- OMEC (Open Mobile Evolved Core)
- ONOS (Open Network Operating System)



	Aether	COMAC	CORD	SD-RAN	OMEC	ONOS
Aether		X	X	X	X	X
COMAC	X		X	X	X	X
CORD	X	X				
SD-RAN	X	X				X
OMEC	X	X				
ONOS	X	X		X		

II. 오픈소스 프로젝트

- 텔코(Telco)를 위한 오픈소스 프로젝트 생태계
- 리눅스재단
- Workloads with the (telco) ecosystem
- Anuket
- Hyperledger Telecom Special Interest Group
- Cellular network 아키텍처
- Building blocks of open source
- Test setup with Layer 1 software modules
- FlexRAN
- TeraFlow
- Open Air Interface

II. 오픈소스 프로젝트

□ 텔코(Telco)를 위한 오픈소스 프로젝트 생태계

- 오픈스택 재단 (OpenStack Foundation)
- 리눅스 재단 (Linux Foundation)
 - CNCF (Cloud Native Computing Foundation) Telecom User Group
 - **Hyperledger** 의 **Telecom SIG** (<https://wiki.hyperledger.org/display/TCSIG/Telecom+SIG>)
 - **Acumos** [LF AI Foundation]
 - **OPNFV** (Open Platform for NFV)
 - **CNTT** (Common NFVI Telecommunications Taskforce)
 - **Anuket** (OPNFV+CNTT) **2021년
 - **ONAP** (Open Network Automation Platform)
- **OCP** (Open Compute Project)
- **ONF** (Open Networking Foundation)
- **TOSCA** (Topology Orchestration Specification for Cloud Applications) 표준
- **Cloudfify**
- **TeraFlow**
- **Public Cloud**의 오픈소스 서비스 (AWS, Azure, ..)

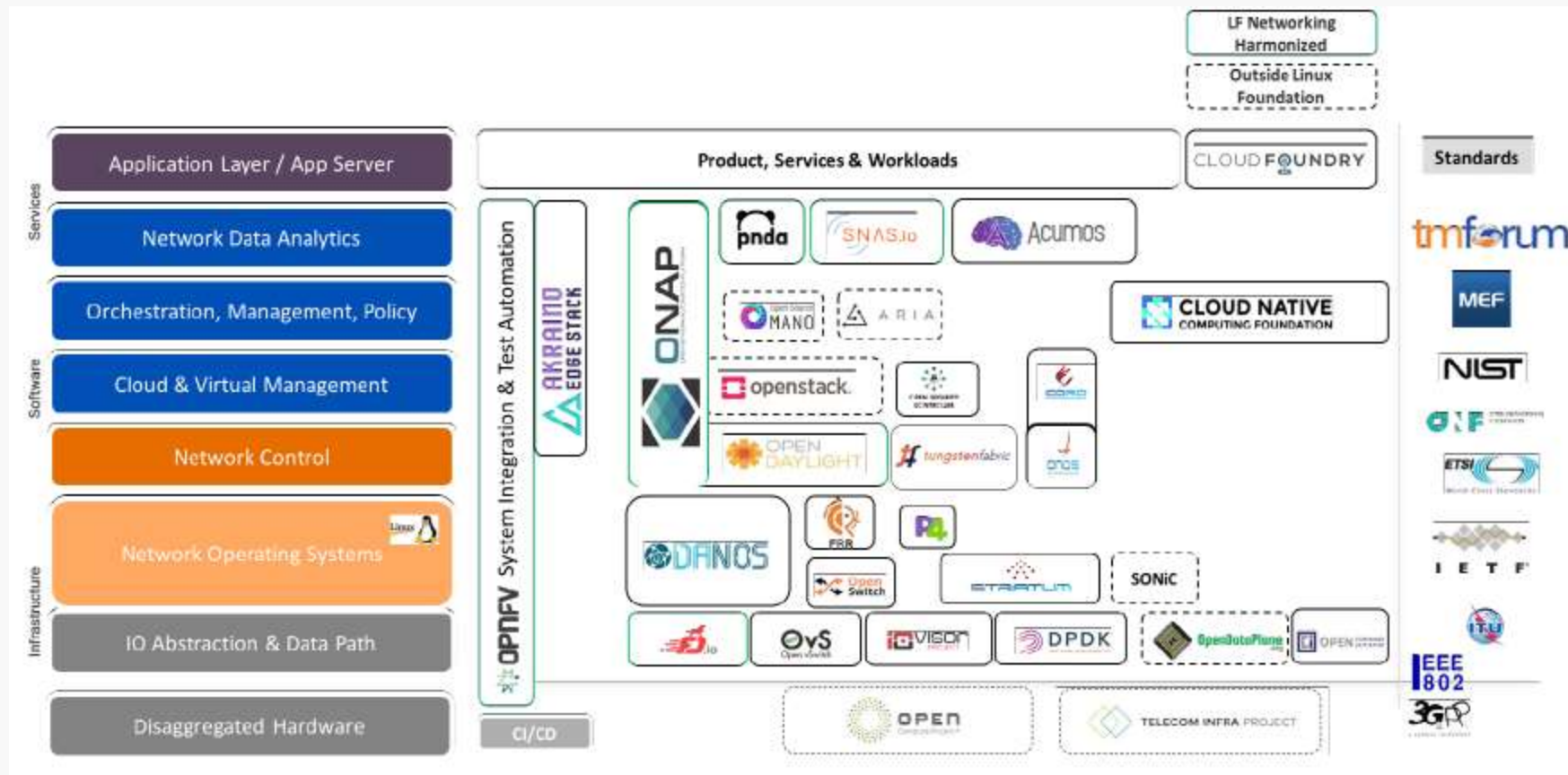
II. 오픈소스 프로젝트

□ 리눅스재단 (예: Featured LFN for 5G Capabilities)

- ONAP SDN Controller for Radio (SDN-R) based on OpenDaylight
- High-performance, flexible 5G user plane with FD.io and VPP
- 5G Cloud Native Network POC
- O-RAN Software Community for the creation of software for the Radio Access Network (RAN)
- Tungsten Fabric and Akraino for SDN/NFV for 5G and Edge Use Cases
- LF Training Course: Open Source and the 5G Transition

II. 오픈소스 프로젝트

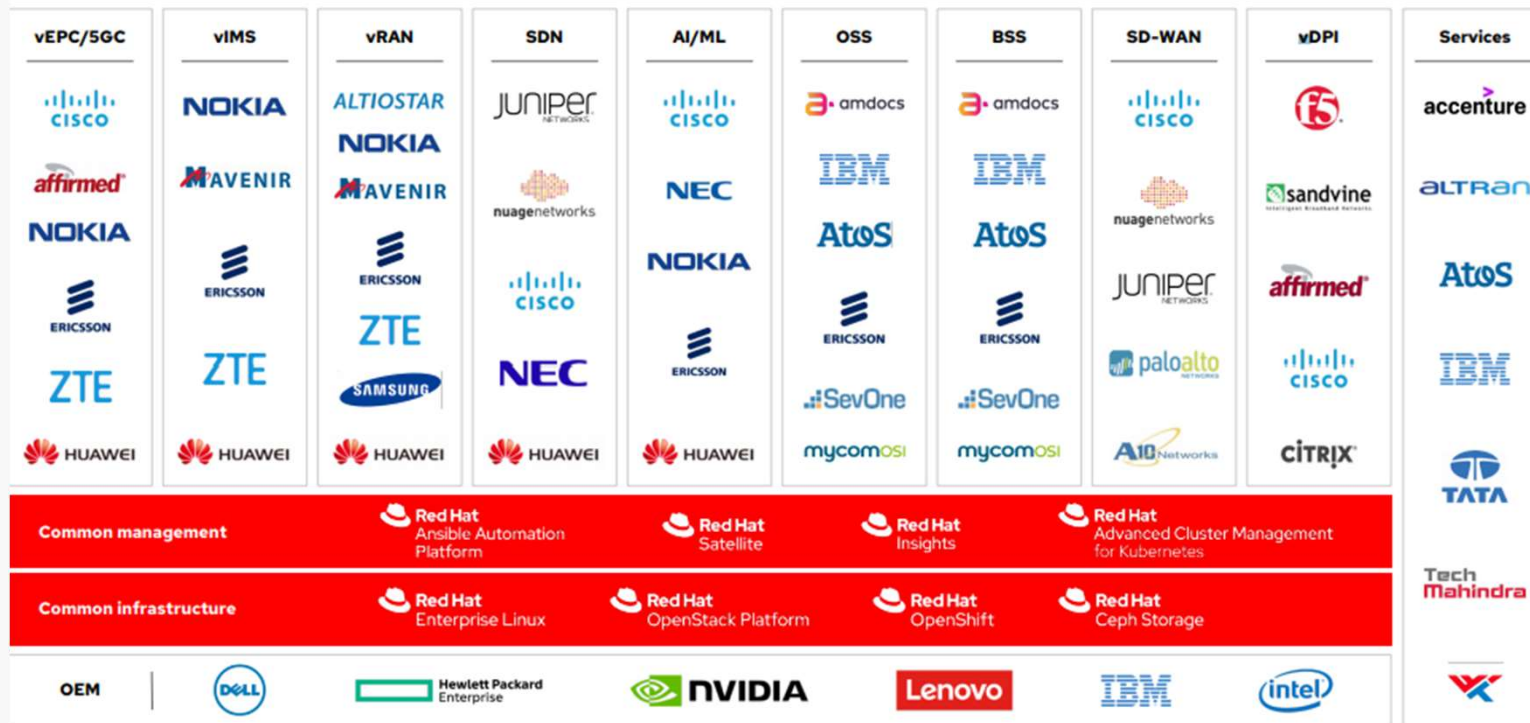
□ All Projects on One Page



II. 오픈소스 프로젝트

□ Workloads with the (telco) ecosystem (예: Red hat)

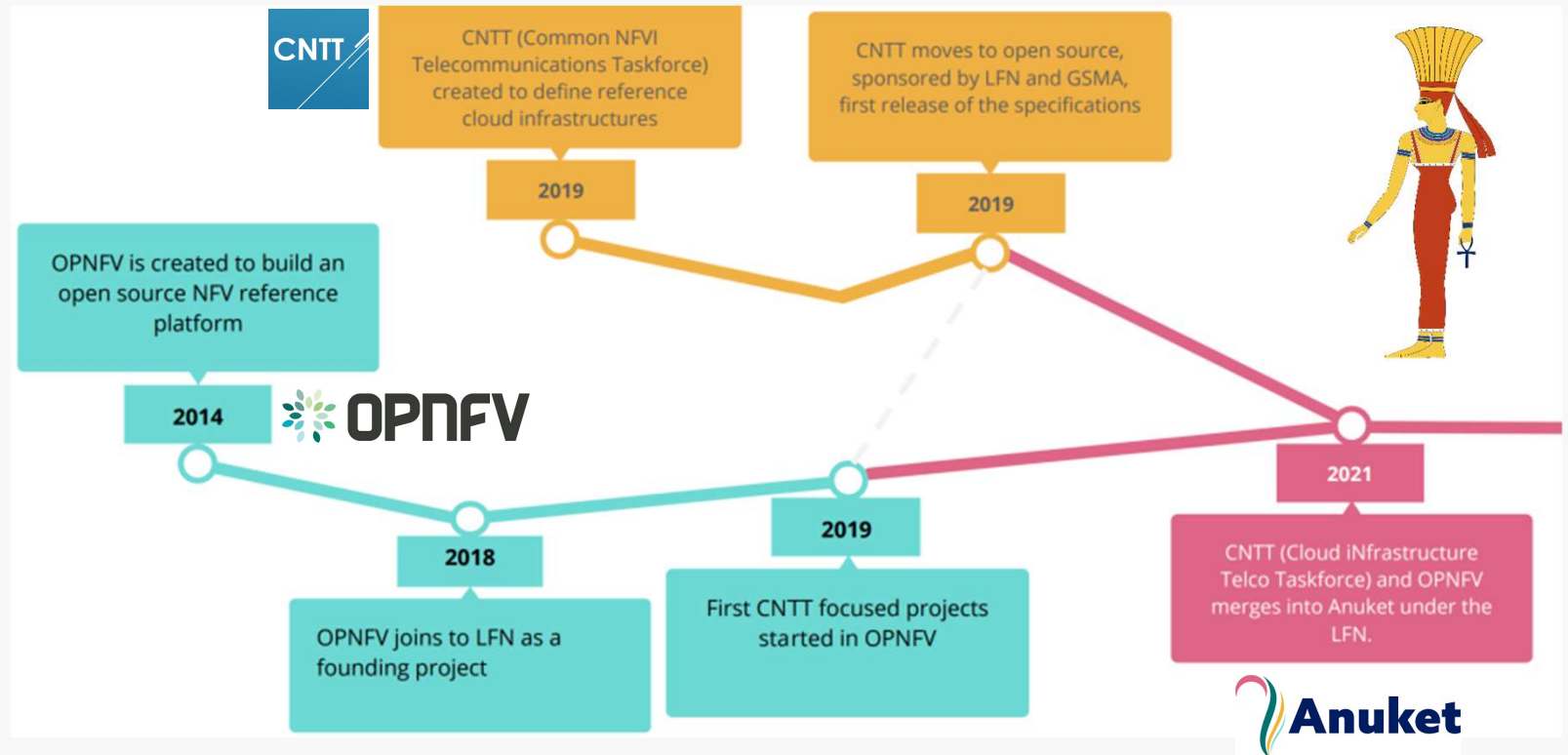
▪ Red hat Telco 생태계 (예)



II. 오픈소스 프로젝트

□ Anuket

- OPNFV (Open Platform for NFV)
- CNTT (Common NFVI Telecommunications Taskforce)



출처: <https://anuket.io/>

II. 오픈소스 프로젝트

□ Anuket

- End to end Technology Lifecycle from Requirements to Implementation
- Aligned with Operator drivers
- Harnesses Technology for Deployment



- Operator Driven Common Requirements
- Conceptual Reference Model
- Architecture Definition
- Specifications

- Implementation & Integration
- Distributed Community Labs
- Functional & Performance Testing
- Conformance Programs
- Code
- CI/CD

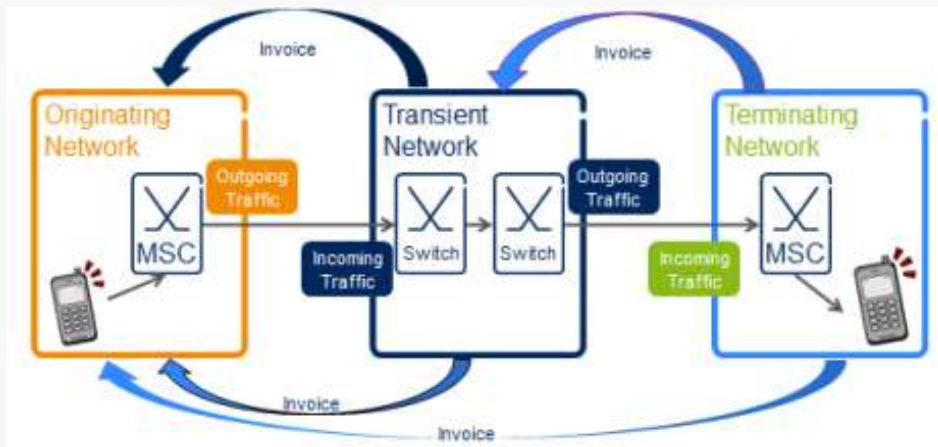
- End to end Technology Lifecycle from Requirements to Implementation
- Aligned with Operator drivers
- Harnesses Technology for Deployment

출처: <https://anuket.io/>

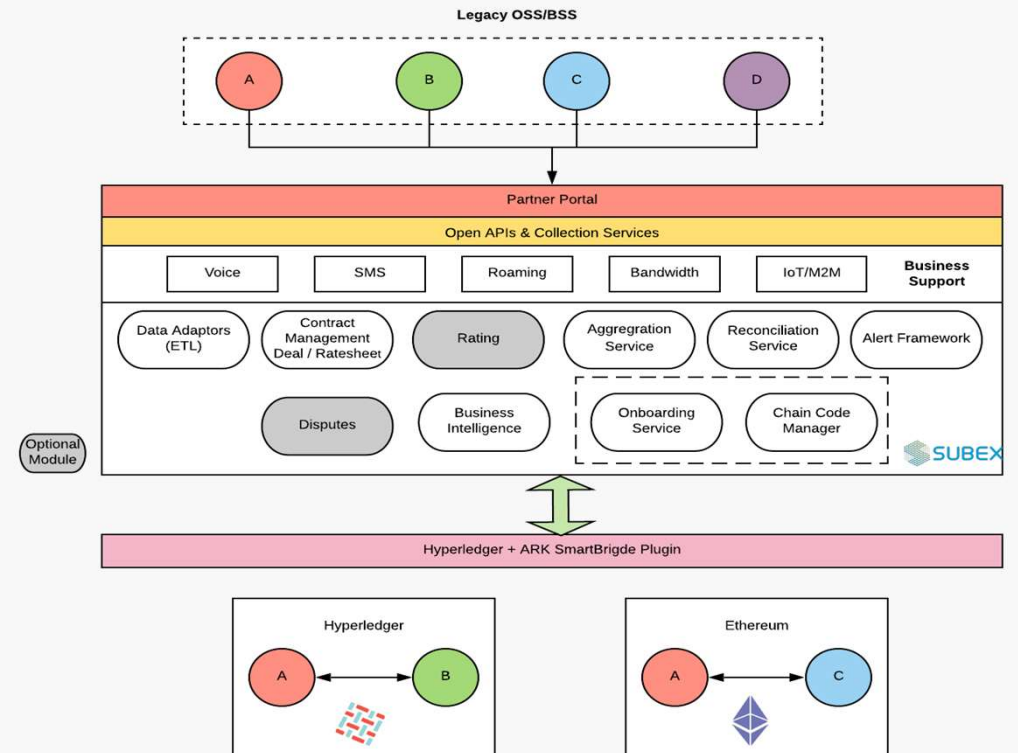
II. 오픈소스 프로젝트

□ Hyperledger Telecom Special Interest Group

- Proposed solution is a event agnostic platform that can manage Voice, SMS, Roaming, IoT, Content or any other event settlement scenarios making it is true convergent solution.



출처: <https://wiki.hyperledger.org/display/TCSIG>



II. 오픈소스 프로젝트

- ❑ Cloud Edge Computing: 단순 데이터센터 보다 큰 의미
- ❑ Akraino, Airship, StalingX (협력)
- ❑ Killer Service Solution 탑재 필요

OpenStack

(코드 개발)



Linux Foundation

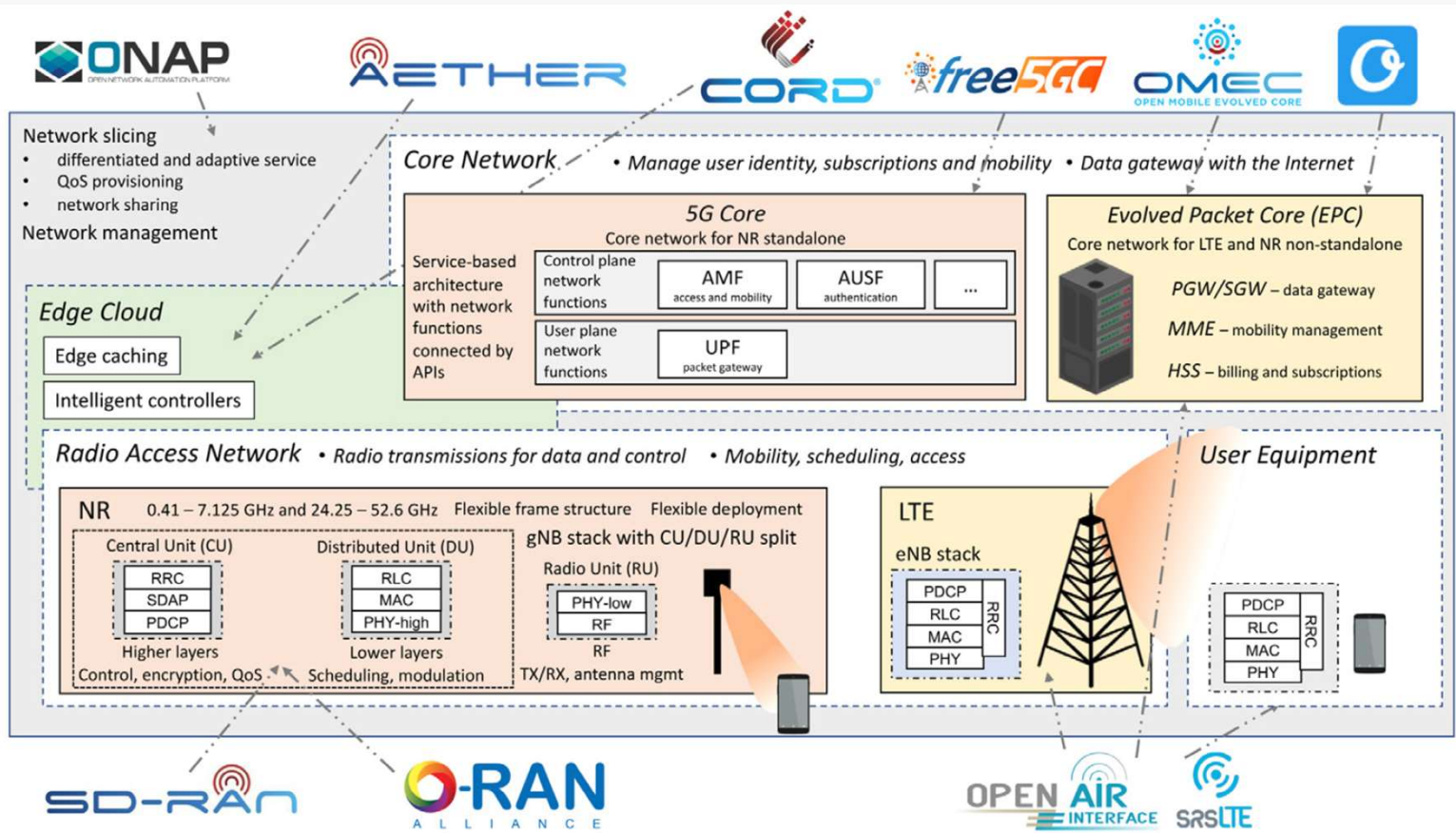
(Use Case 정의,
Integration, 검증)



출처: https://wiki.openstack.org/wiki/Edge_Computing_Group?fbclid=IwAR3GNTB5_2IOJO-SvaGsmhCC2jhLxG9X-IST021v-mlfG-TxsR7jiPtrM80

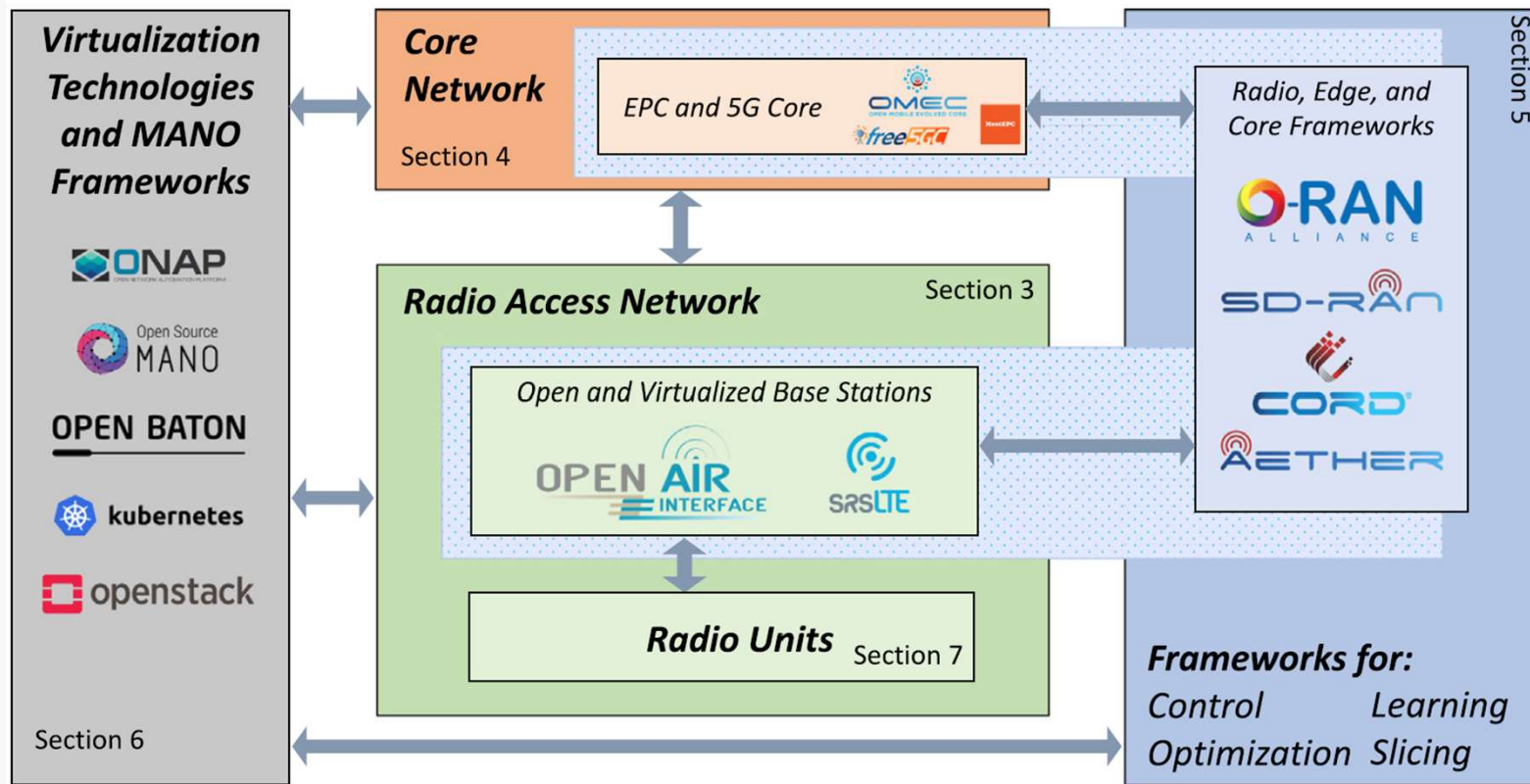
II. 오픈소스 프로젝트

□ Cellular network 아키텍처



II. 오픈소스 프로젝트

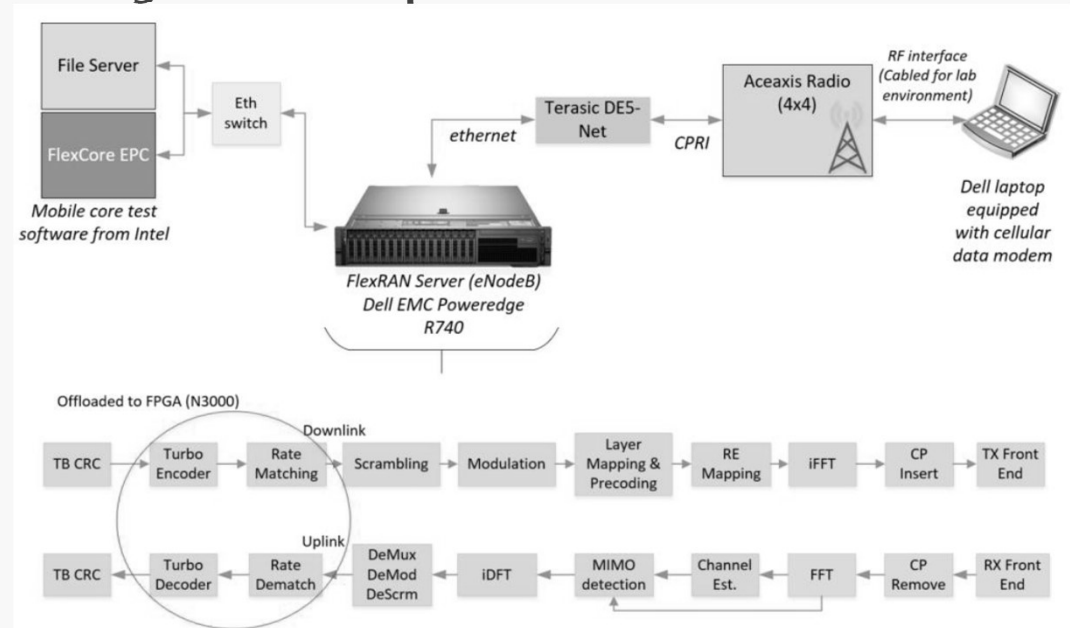
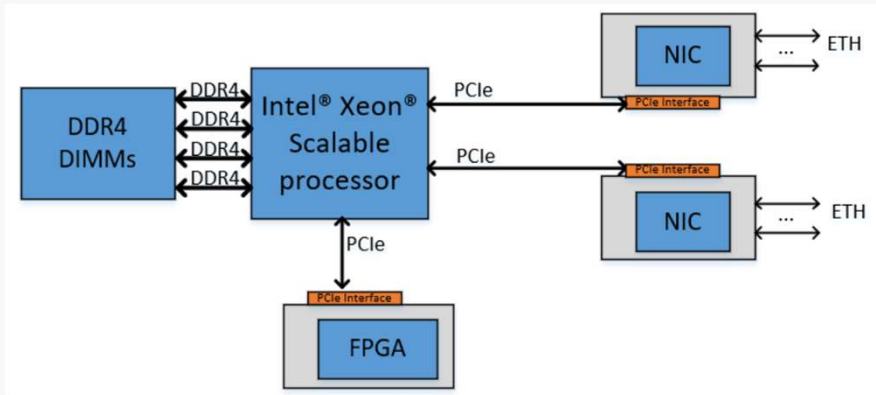
- The main building blocks of open source, programmable and virtualized 5G networks with their components and technologies.



II. 오픈소스 프로젝트

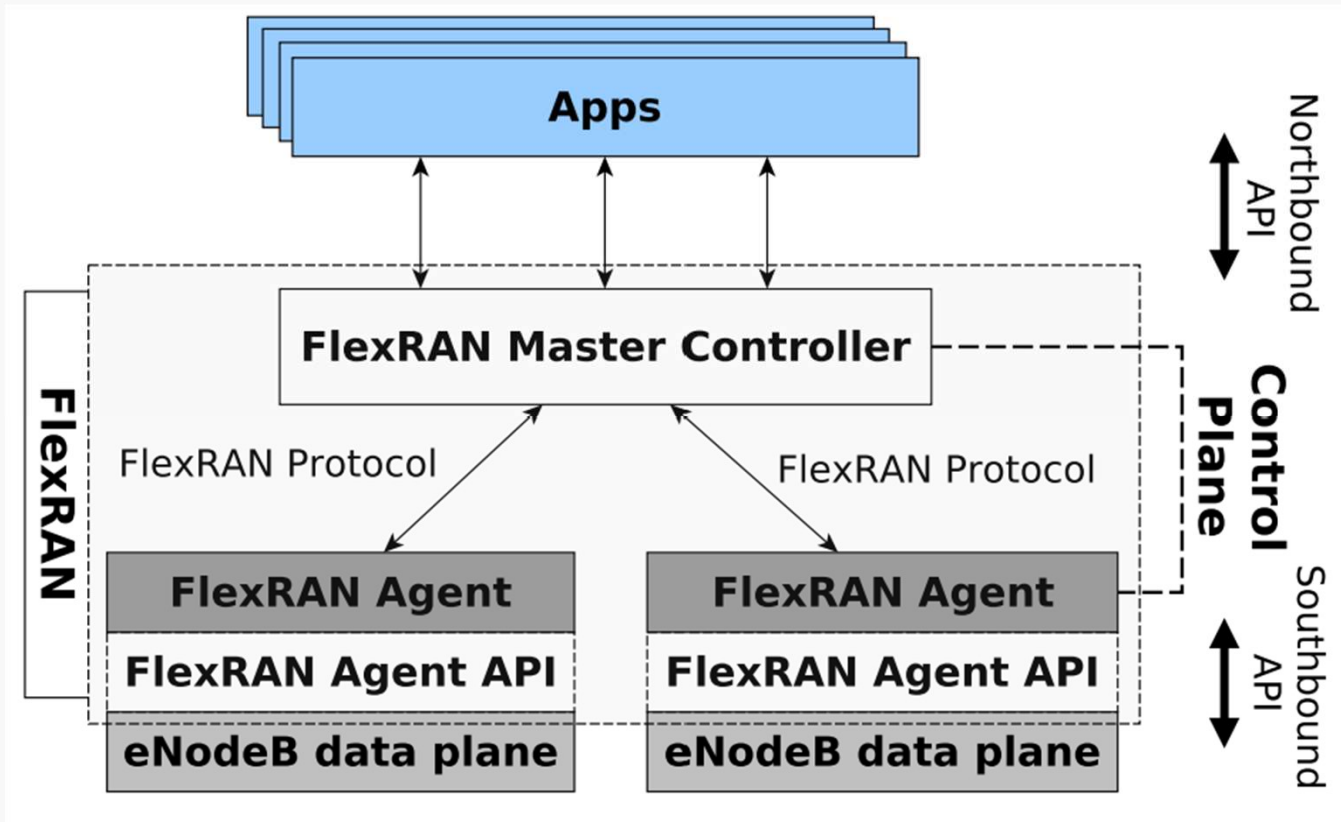
□ Test setup in Dell lab, with Layer 1 software modules

- PowerEdge R740: N3000 network card, an Intel X520 Ethernet network adapter, two Intel® Xeon® Gold 6148 CPUs at 2.4GHz, 256MB of RAM.
- The server was running CentOS (7.5.1804)
- FlexRAN version 18.12, which required DPDK version 18.08, For the FPGA offload, patches released in versions 19.03 were introduced along with DPDK patches



II. 오픈소스 프로젝트

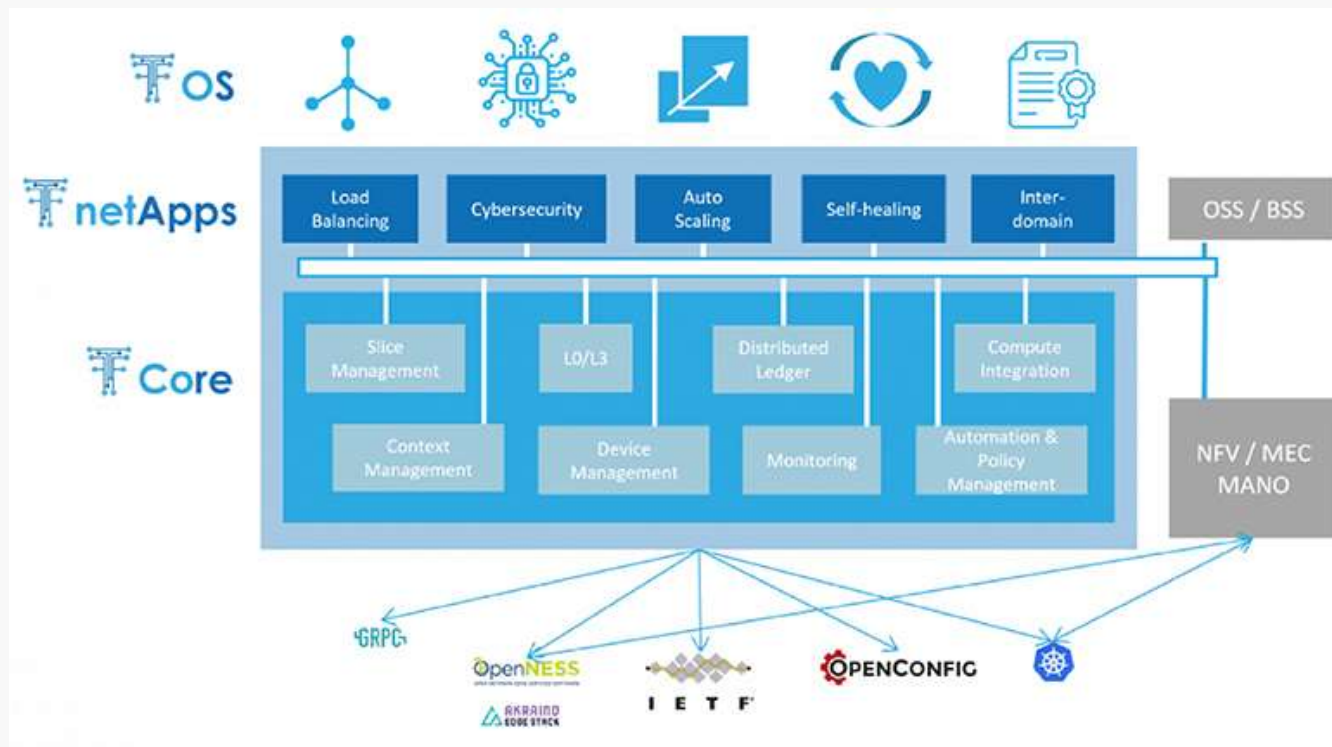
- **FlexRAN**: A Flexible and Programmable Platform for Software-Defined Radio Access Networks



출처: A Flexible and Programmable Platform for Software-Defined Radio Access Networks, Xenofon Foukas and 4 others

II. 오픈소스 프로젝트

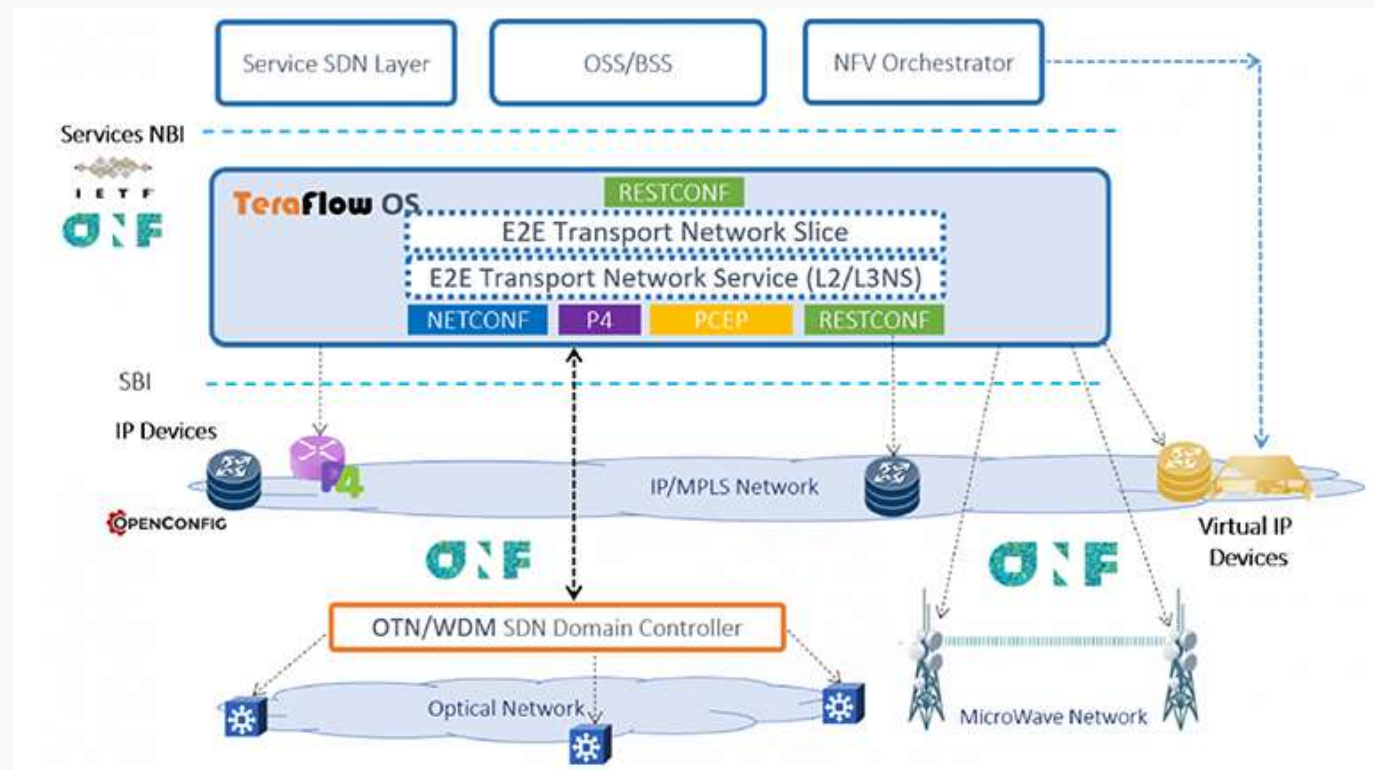
- ❑ TeraFlow: an ongoing project funded by the European Commission, which aims to develop a carrier-grade SDN controller for networks beyond 5G.



출처: https://www.infinera.com/blog/whats-next-for-sdn-control/tag/software-and-automation/?fbclid=IwAR0Pb29BuNOT8ipO7GP8-CuteSqANFdOi1ICT_gLPeL7RngRb8rWujS2CA

II. 오픈소스 프로젝트

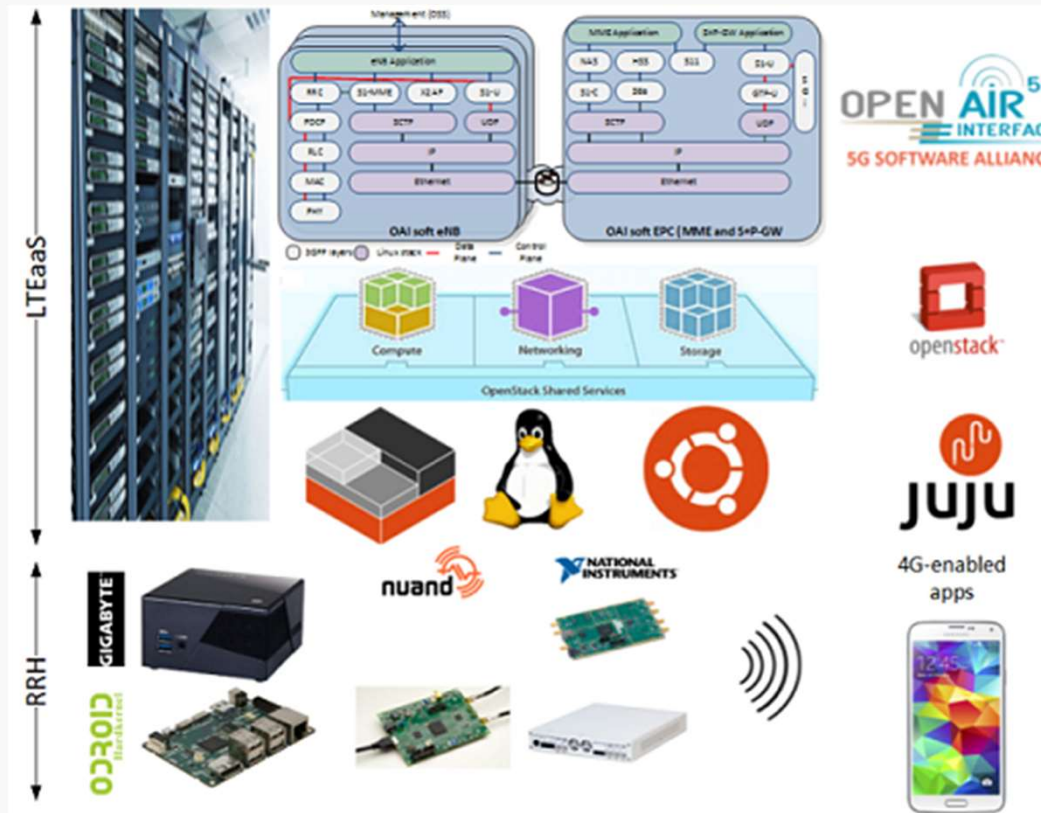
□ TeraFlow use case



출처: https://www.infinera.com/blog/whats-next-for-sdn-control/tag/software-and-automation/?fbclid=IwAR0Pb29BuNOT8ipO7GP8-CuteSqANFdOi1ICT_gLPeL7RngRb8rWujS2CA

II. 오픈소스 프로젝트

□ Open Air Interface use case



출처: https://www.openairinterface.org/wp-content/uploads/2015/06/cran_figure1.png

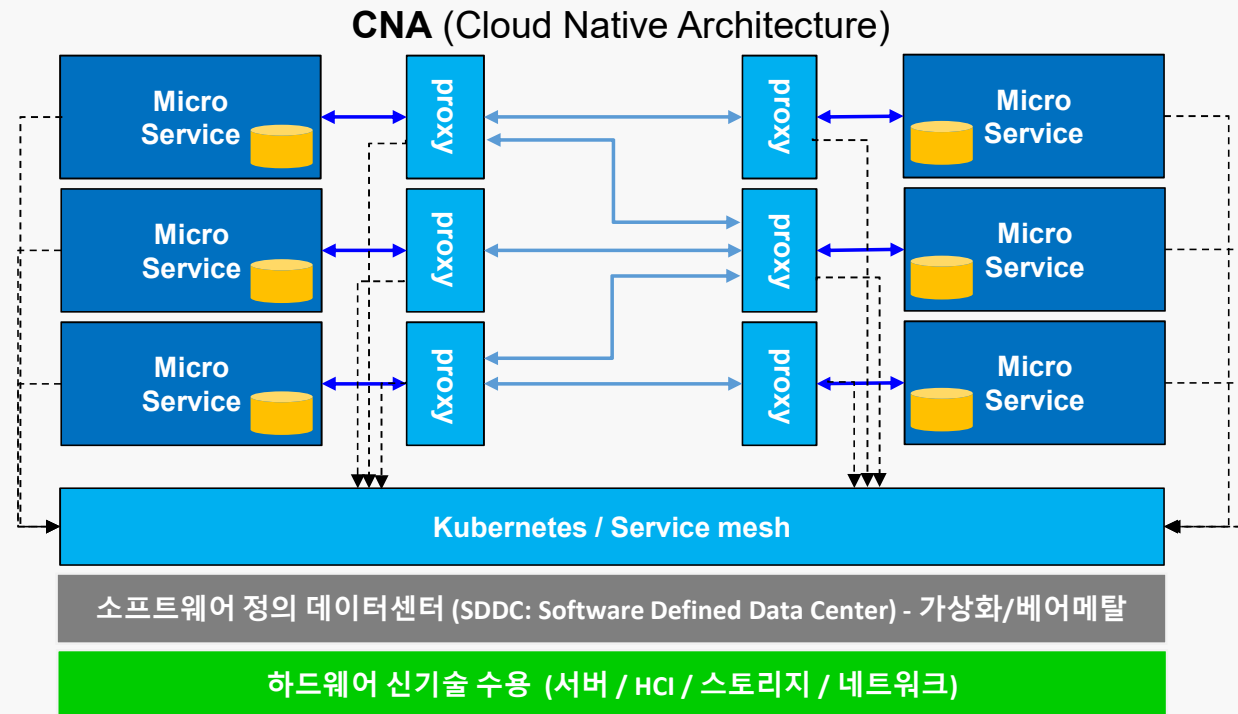
III. 응용 기술

- 클라우드 네이티브 아키텍처(Cloud Native Architecture)
- Edge Cloud Solution
- Red Hat OpenShift as a 5G NFV platform
- OpenStack
- KubeVirt Networking

III. 응용 기술

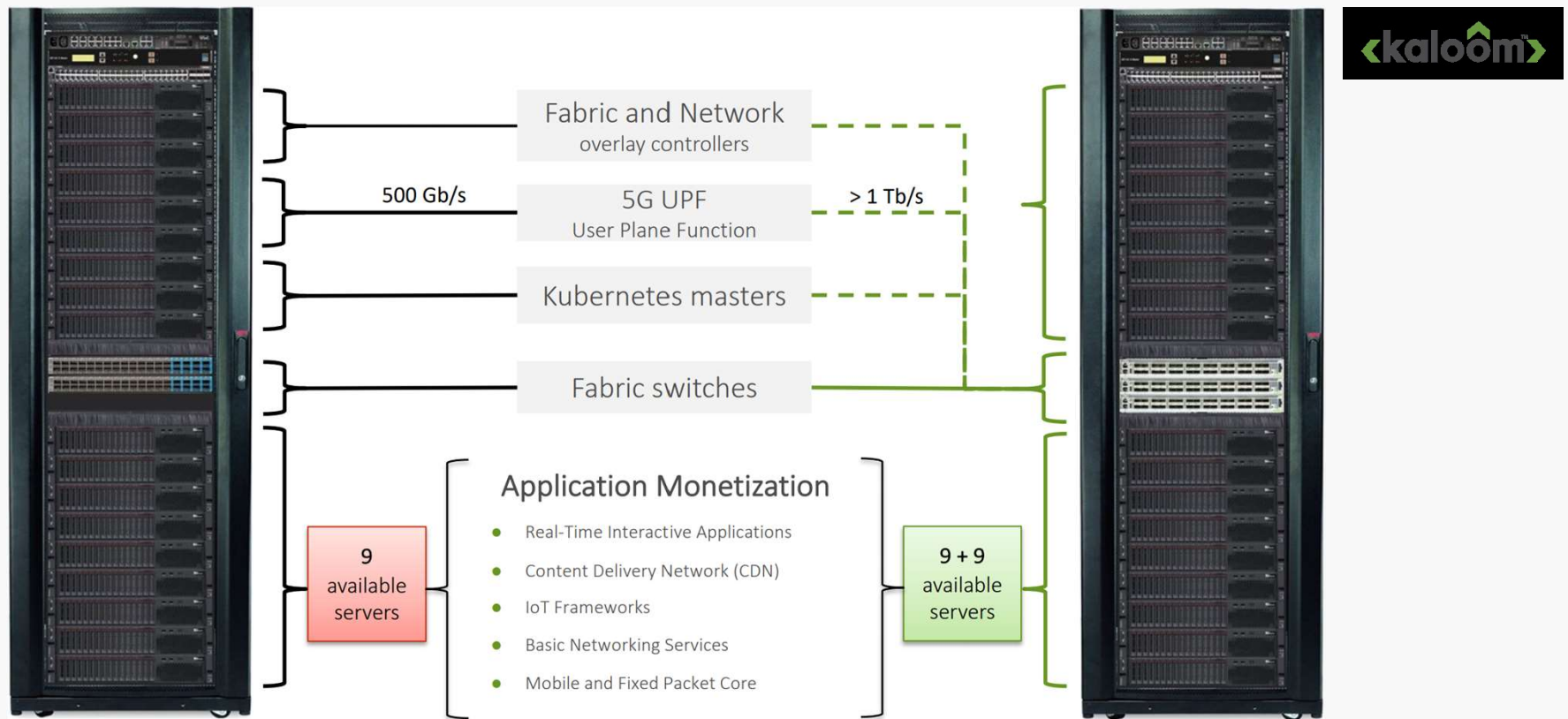
□ 클라우드 네이티브 아키텍처(Cloud Native Architecture)

- MSA(마이크로서비스 기반) 수용 클라우드 네이티브 기술 발전 수용 체계
- 온프레미스(On-premises) 인프라를 위한 SDDC 기반 데이터센터



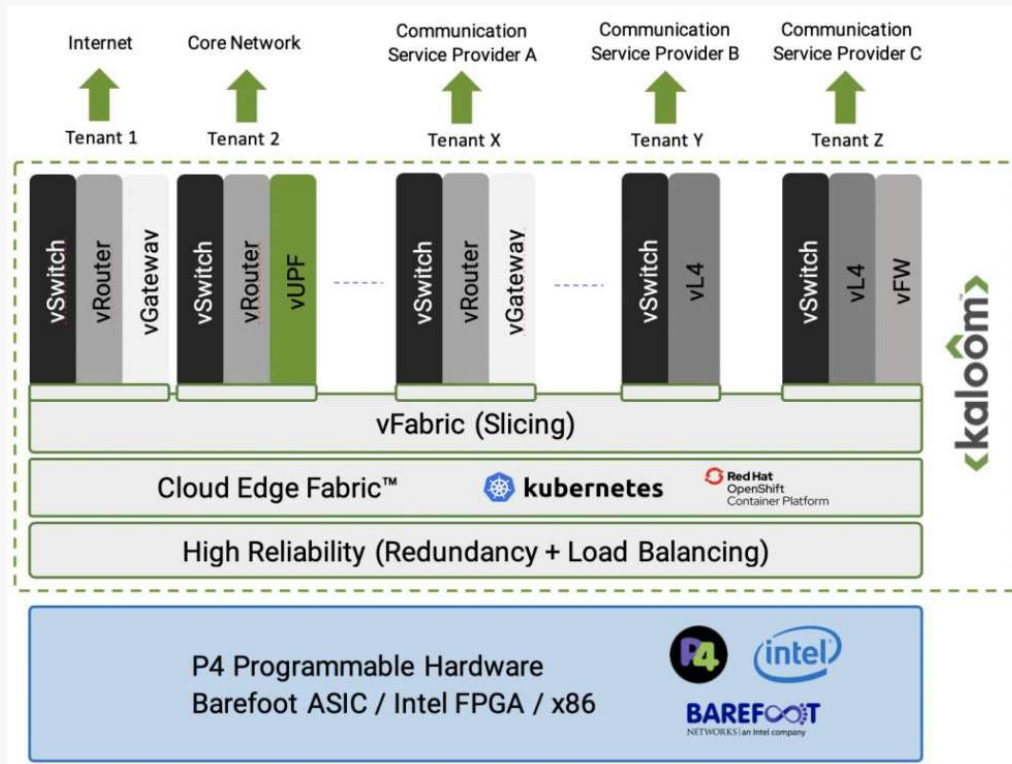
III. 응용 기술

□ Edge Cloud Solution

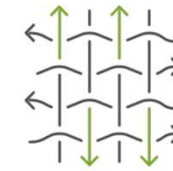


III. 응용 기술

□ Edge Cloud Solution



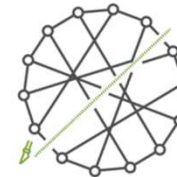
Kaloôm™ Copyright



Fully Programmable
Future-Proof Networking



Autonomous
Self-Discovering/ Self-Forming



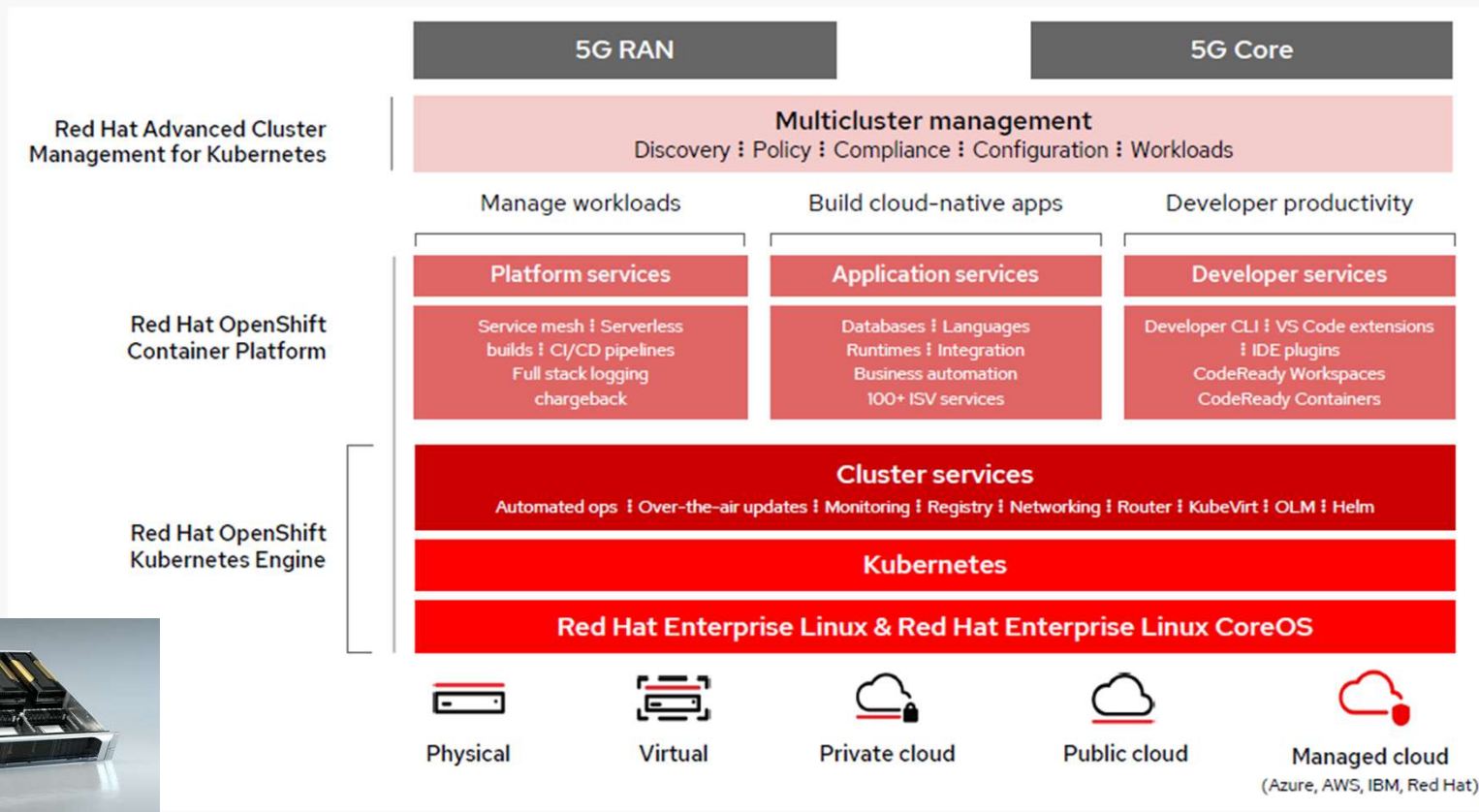
Fully Virtualizable
Fabric Slicing (vFabric)



Network Function
Integration

III. 응용 기술

□ Red Hat OpenShift as a 5G NFV platform



III. 응용 기술

□ OpenStack is developed and released around 6-month cycles

Series	Status	Initial Release Date	Next Phase	EOL Date
Xena	Development	2021-10-06 <i>estimated (schedule)</i>	Development <i>estimated 2021-04-14</i>	
Wallaby	Maintained	2021-04-14	Extended Maintenance <i>estimated 2022-10-14</i>	
Victoria	Maintained	2020-10-14	Extended Maintenance <i>estimated 2022-04-18</i>	
Ussuri	Maintained	2020-05-13	Extended Maintenance <i>estimated 2021-11-12</i>	
Train	Extended Maintenance (see note below)	2019-10-16	Unmaintained <i>TBD</i>	
Stein	Extended Maintenance (see note below)	2019-04-10	Unmaintained <i>TBD</i>	
Rocky	Extended Maintenance (see note below)	2018-08-30	Unmaintained <i>TBD</i>	
Queens	Extended Maintenance (see note below)	2018-02-28	Unmaintained <i>TBD</i>	
Pike	Extended Maintenance (see note below)	2017-08-30	Unmaintained <i>TBD</i>	
Ocata	Extended Maintenance (see note below)	2017-02-22	Unmaintained <i>estimated 2020-06-04</i>	
Newton	End Of Life	2016-10-06		2017-10-25
Mitaka	End Of Life	2016-04-07		2017-04-10
Liberty	End Of Life	2015-10-15		2016-11-17
Kilo	End Of Life	2015-04-30		2016-05-02
Juno	End Of Life	2014-10-16		2015-12-07
Icehouse	End Of Life	2014-04-17		2015-07-02
Havana	End Of Life	2013-10-17		2014-09-30
Grizzly	End Of Life	2013-04-04		2014-03-29
Folsom	End Of Life	2012-09-27		2013-11-19
Essex	End Of Life	2012-04-05		2013-05-06
Diablo	End Of Life	2011-09-22		2013-05-06
Cactus	End Of Life	2011-04-15		
Bexar	End Of Life	2011-02-03		
Austin	End Of Life	2010-10-21		

출처: <https://releases.openstack.org/>

III. 응용 기술

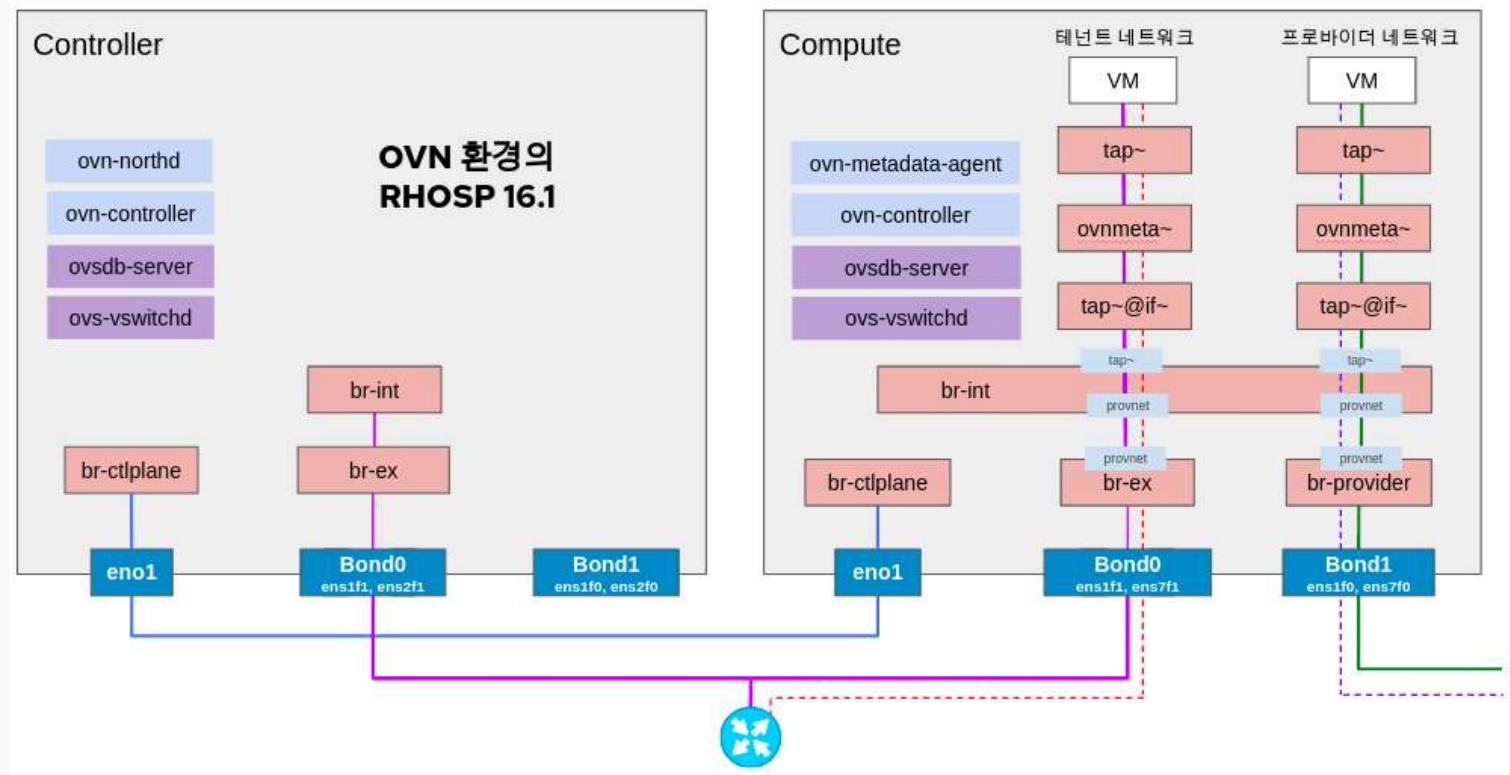
□ OpenStack Release - Wallaby

Release Summary				
Deliverable	Earliest Version	Most Recent Version	Stable Status	Notes
adjutant	2.0.0	2.0.0	Maintained	
aodh	12.0.0	12.0.0	Maintained	release notes
barbican	12.0.0	12.0.0	Maintained	release notes
blazar	7.0.0	7.0.0	Maintained	release notes
ceilometer	16.0.0	16.0.0	Maintained	release notes
cinder	18.0.0	18.0.0	Maintained	release notes
cloudkitty	14.0.0	14.0.0	Maintained	release notes
cyborg	6.0.0	6.0.0	Maintained	release notes
designate	12.0.0	12.0.0	Maintained	release notes
ec2-api	12.0.0	12.0.0	Maintained	
freezer	10.0.0	10.0.0	Maintained	
glance	22.0.0	22.0.0	Maintained	release notes
heat	16.0.0	16.0.0	Maintained	release notes
horizon	19.0.0	19.2.0	Maintained	release notes
ironic	16.1.0	17.0.3	Maintained	release notes
keystone	19.0.0	19.0.0	Maintained	
magnum	12.0.0	12.0.0	Maintained	
manila	12.0.0	12.0.0	Maintained	release notes
masakari	11.0.0	11.0.0	Maintained	release notes
mistral	12.0.0	12.0.0	Maintained	release notes
monasca-api	6.0.0	6.0.0	Maintained	release notes
monasca-events-api	3.0.0	3.0.0	Maintained	
murano	11.0.0	11.0.0	Maintained	release notes
neutron	18.0.0	18.1.0	Maintained	release notes
nova	23.0.0	23.0.2	Maintained	release notes
octavia	8.0.0	8.0.0	Maintained	release notes
panko	10.0.0	10.0.0	Maintained	release notes
placement	5.0.0	5.0.1	Maintained	release notes
sahara	14.0.0	14.0.0	Maintained	release notes
senlin	11.0.0	11.0.0	Maintained	release notes
solum	10.0.0	10.0.0	Maintained	release notes
storlets	7.0.0	7.0.0	Maintained	release notes
swift	2.27.0	2.27.0	Maintained	release notes
tacker	5.0.0	5.0.0	Maintained	release notes
trove	15.0.0	15.0.0	Maintained	release notes
vitrage	7.4.0	7.4.0	Maintained	release notes
watcher	6.0.0	6.0.0	Maintained	
zaqar	12.0.0	12.0.0	Maintained	
zun	7.0.0	7.0.0	Maintained	release notes

출처: <https://releases.openstack.org/wallaby/index.html>

III. 응용 기술

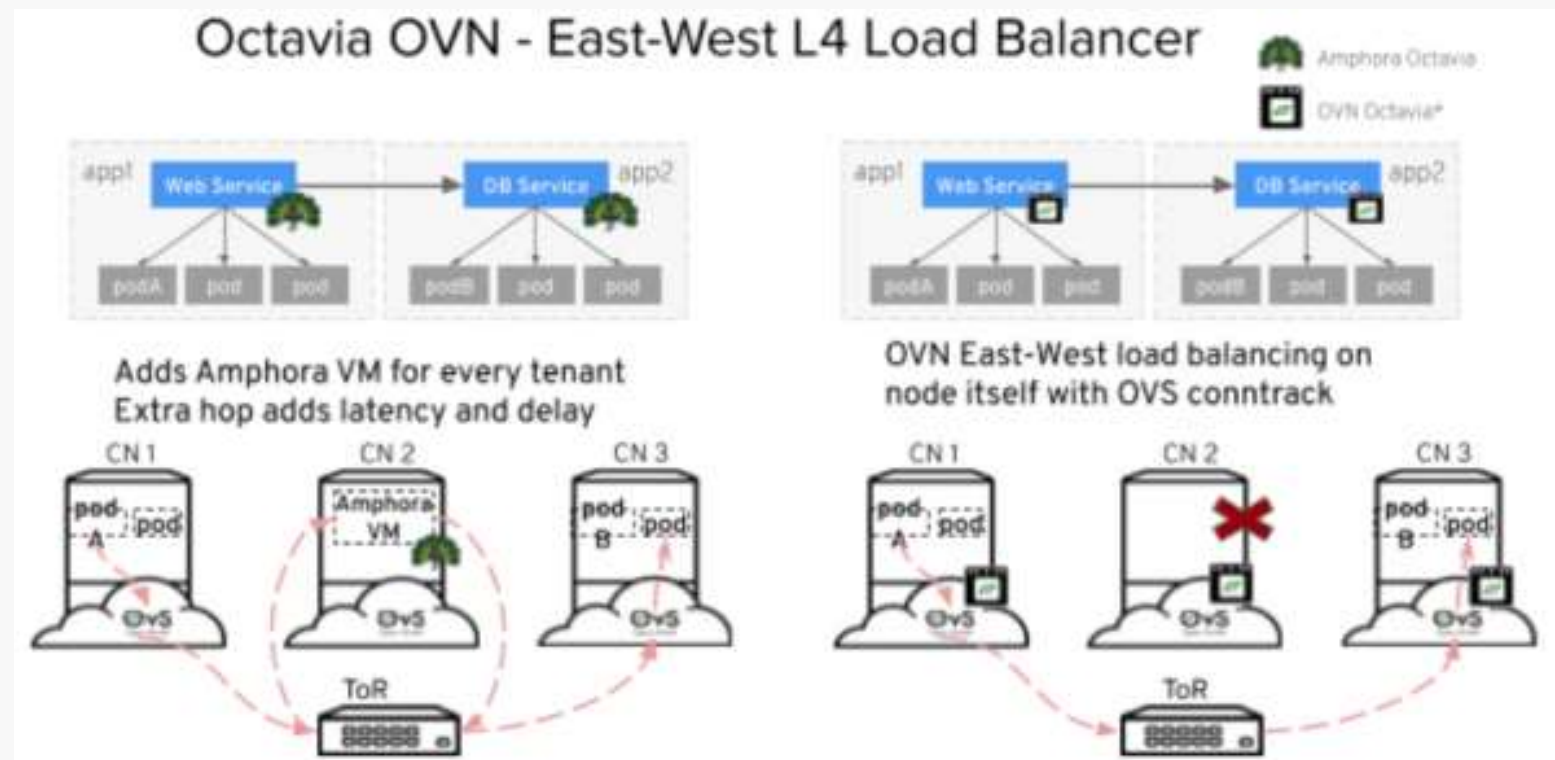
□ Neutron(네트워크)는 ML2기반의 OpenvSwitch 에서 OVN(Open Virtual Network) 사용 가능



출처: <https://naleejang.tistory.com/244?category=415728>

III. 응용 기술

□ Load balancing with Octavia OVN driver

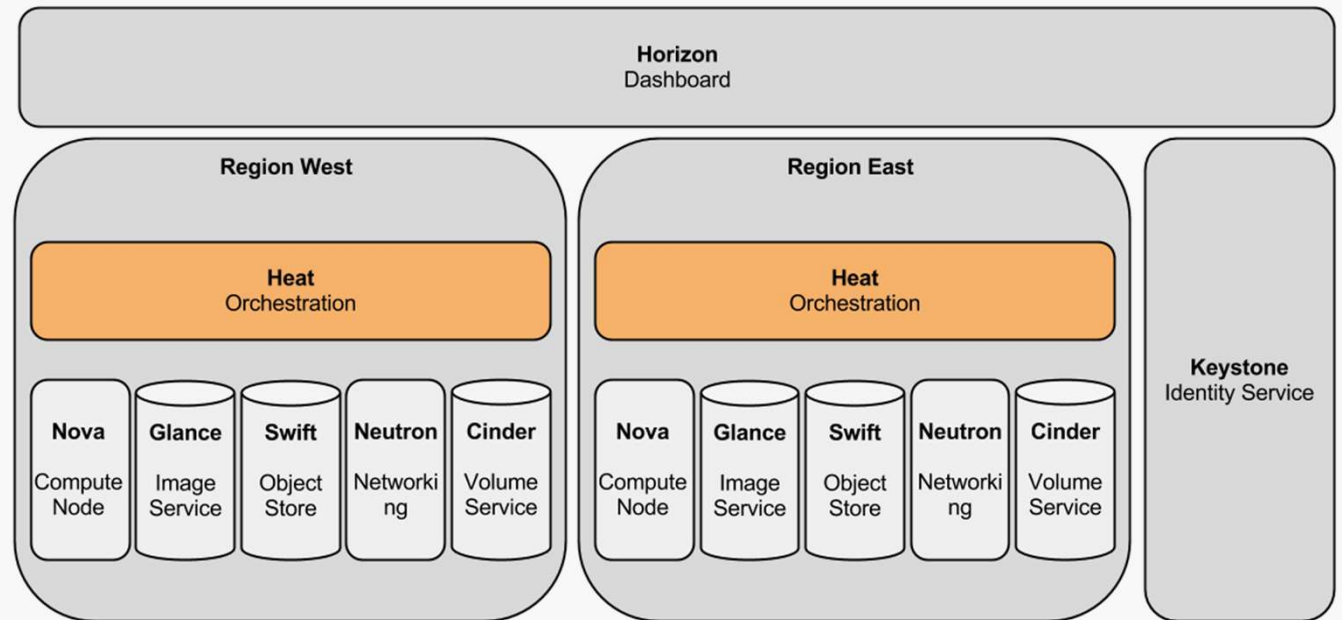


출처: <https://superuser.openstack.org/articles/run-your-kubernetes-cluster-on-openstack-in-production/>

III. 응용 기술

□ Heat

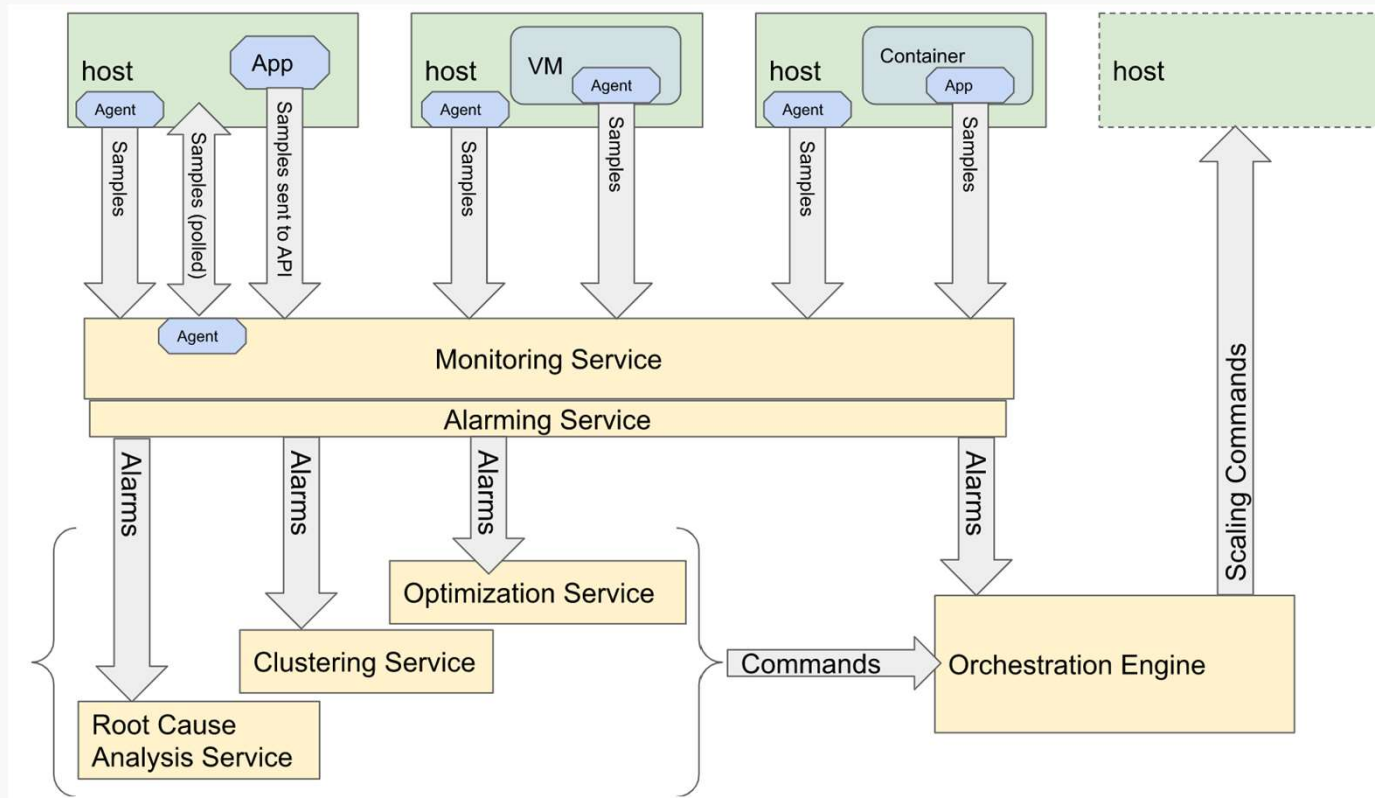
- Orchestration
- Heat/Blueprints/Multi Region Support for Heat
- A Heat template describes the infrastructure for a cloud application in text files which are readable and writable by humans, and can be managed by version control tools



출처: https://wiki.openstack.org/wiki/Heat/Blueprints/Multi_Region_Support_for_Heat

III. 응용 기술

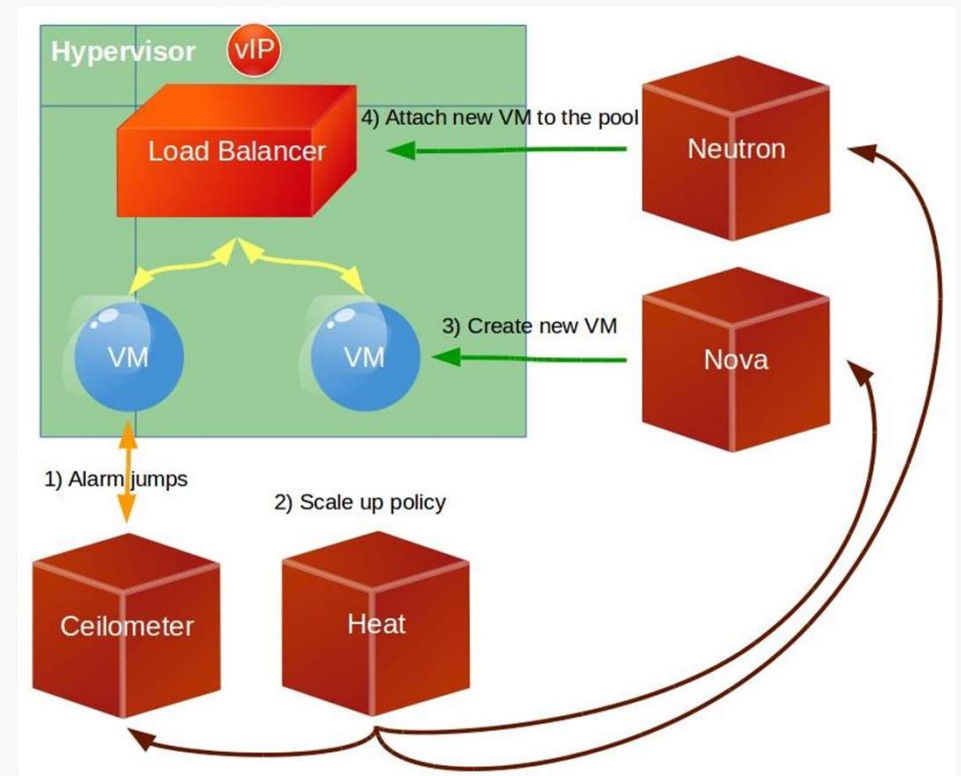
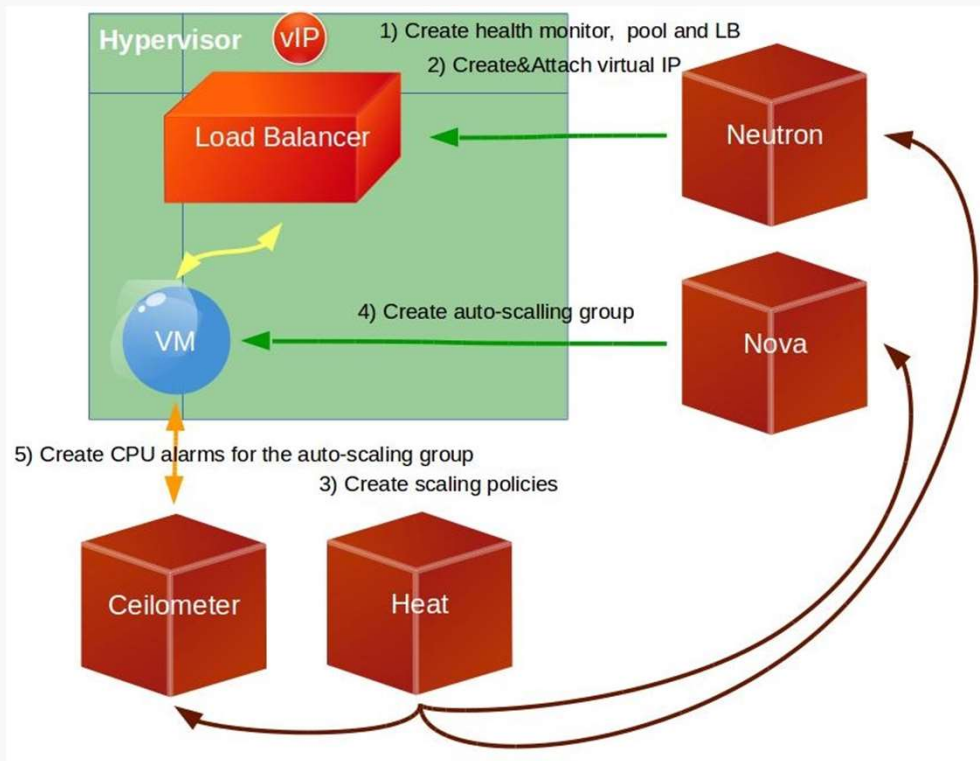
□ Autoscaling



출처: <https://docs.openstack.org/auto-scaling-sig/latest/theory-of-auto-scaling.html>

III. 응용 기술

□ Heat for autoscaling

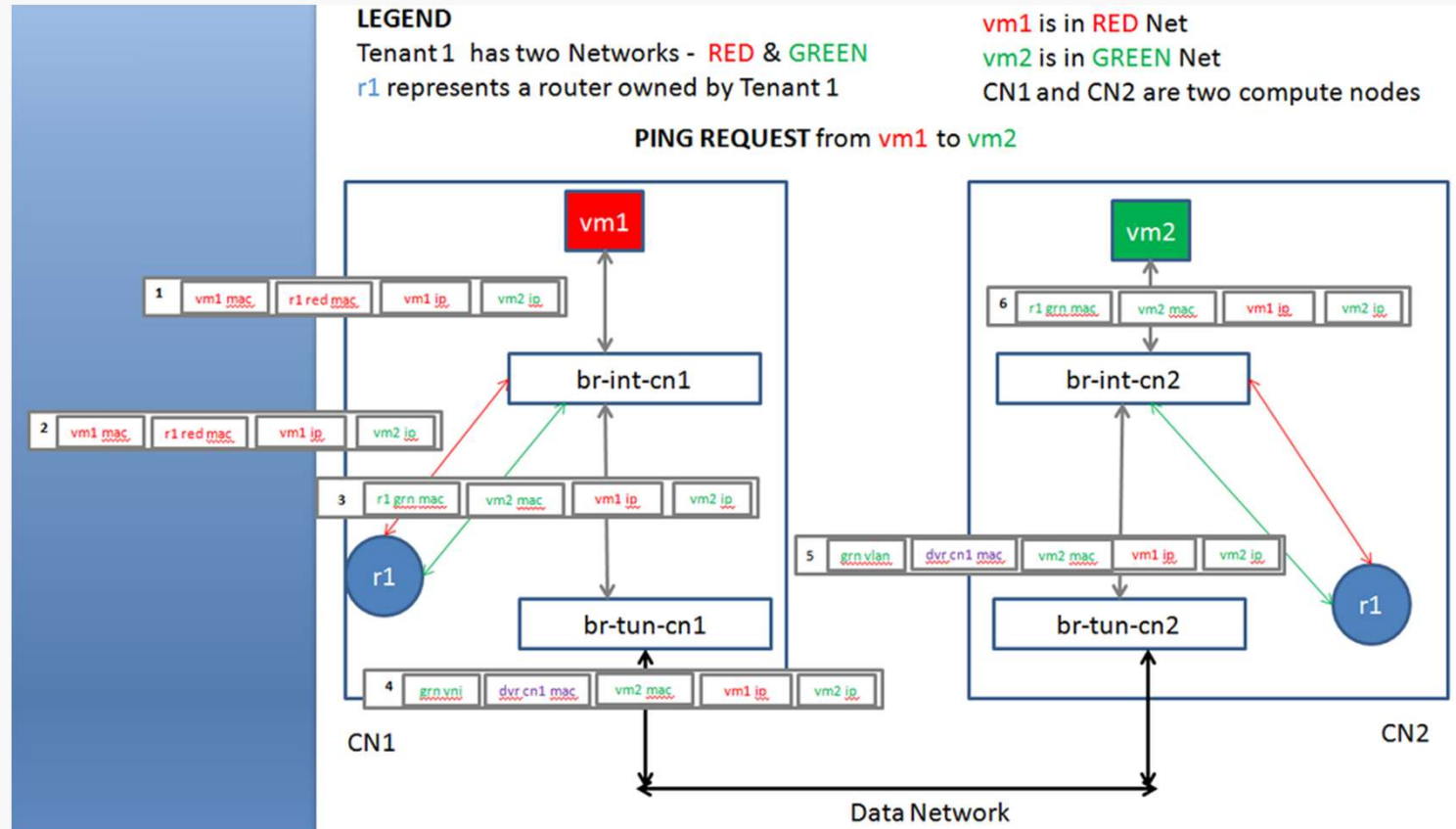


출처: <https://ibm-blue-box-help.github.io/help-documentation/heat/autoscaling-with-heat/>

III. 응용 기술

□ Distributed Routing

- DVR (Distributed Virtual Router)
- 라우팅 경로 단축

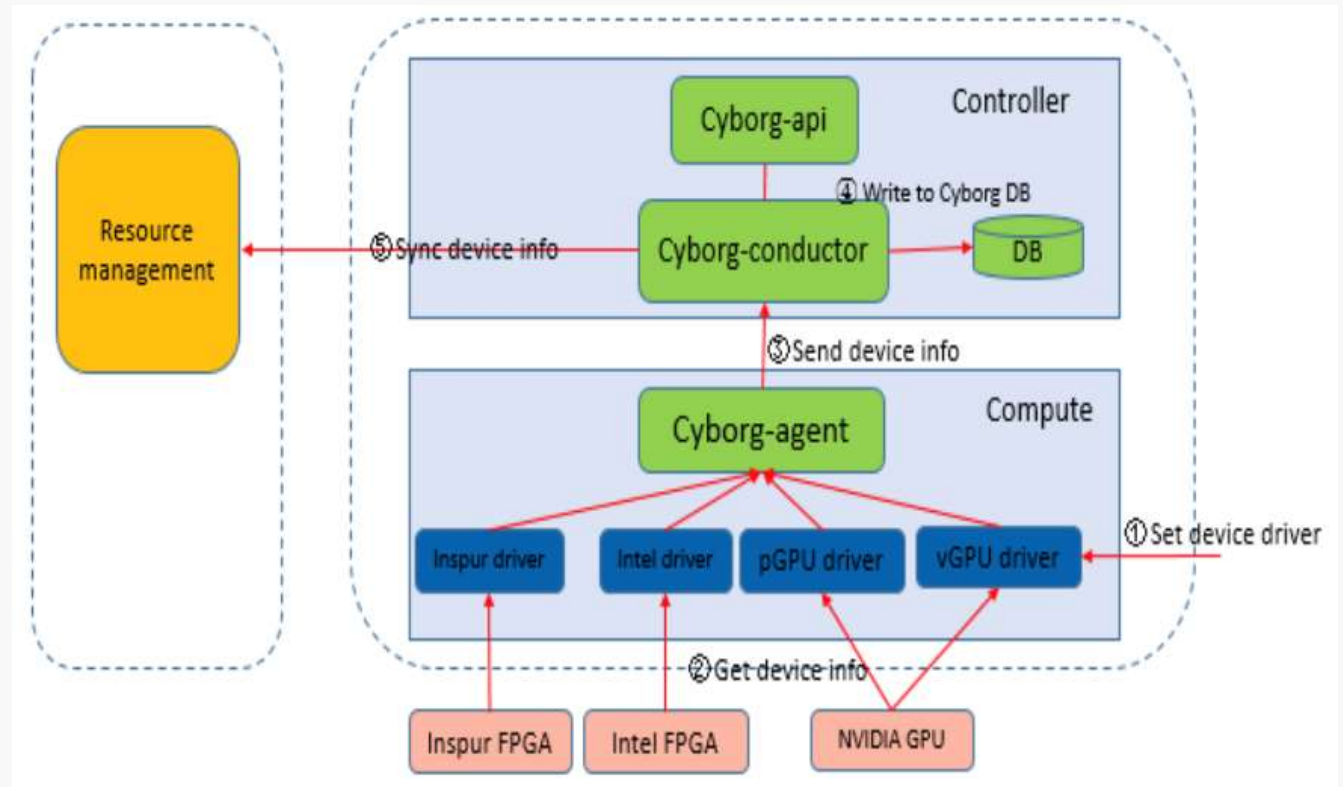


출처: https://wiki.openstack.org/wiki/Neutron/DVR_L2_Agent

III. 응용 기술

□ Cyborg

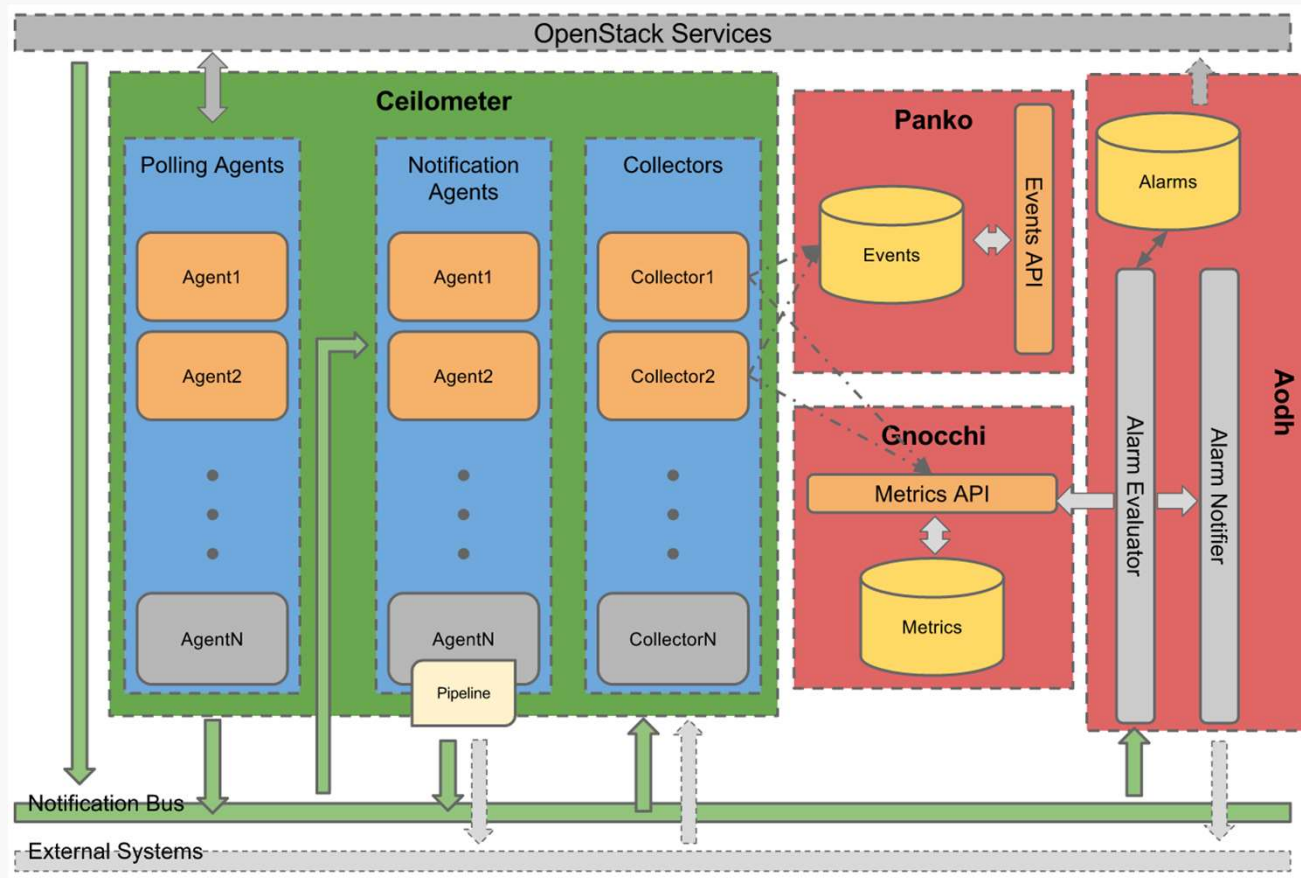
- For SmartNIC, we can program it with OVS image as NFVI function in OpenStack, e.g. N3000, Mellanox CX5 and BF2. (확인/안정화)



출처: <https://superuser.openstack.org/articles/enhancement-of-new-heterogeneous-accelerators-based-on-cyborg/>

III. 응용 기술

□ Ceilometer, Panko and Aodh



III. 응용 기술

□ 적용 기능별 성능 개선 분석

□ EPA Features Covered

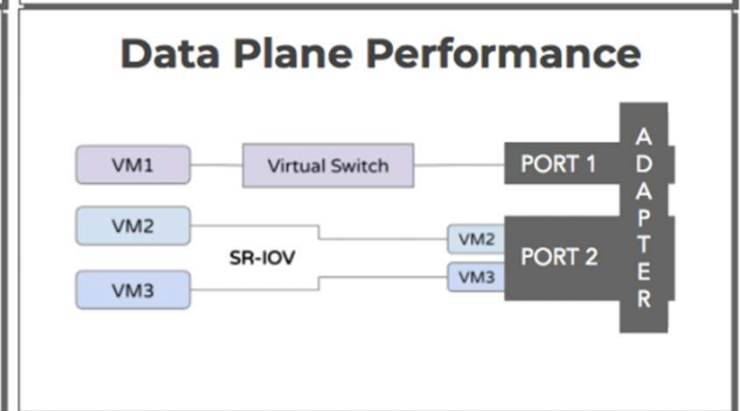
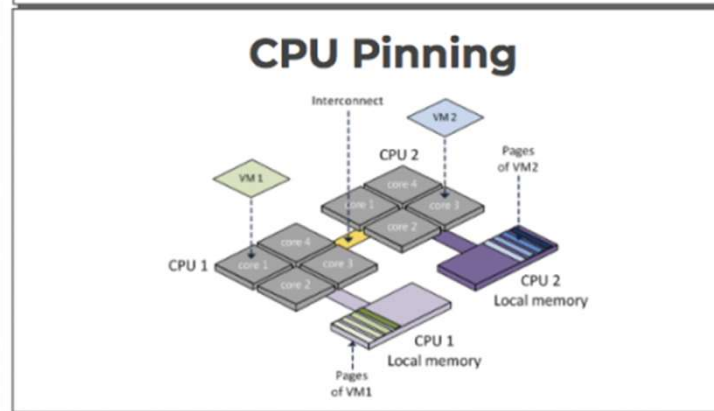
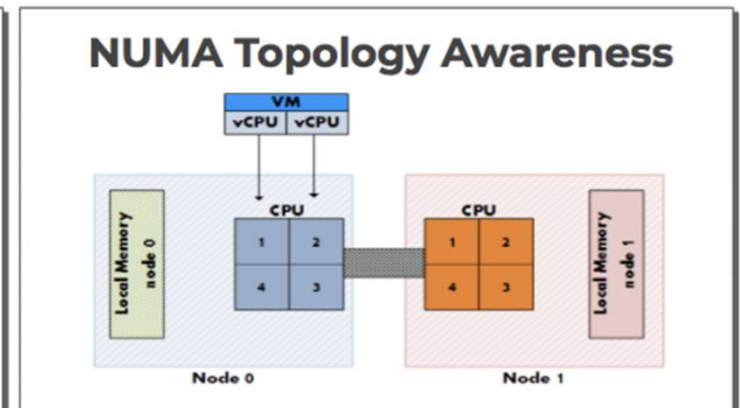
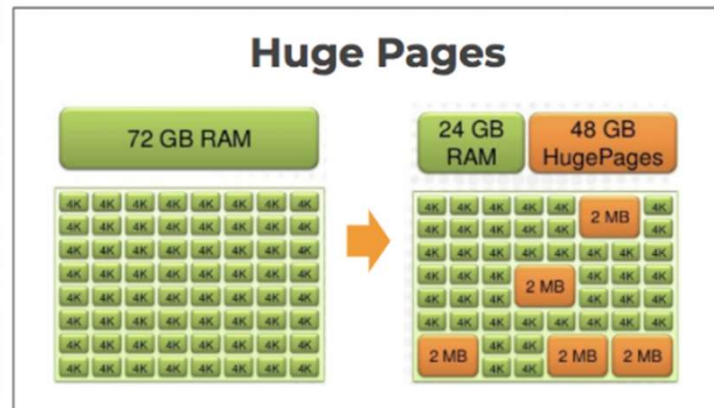
- Host CPU feature request (20~40%)
- PCI passthrough (~8%)
- HugePages* support (10~20%)
- NUMA awareness (~10%)
- IO based NUMA scheduling (~25%)
- CPU pinning (10~20%)
- CPU threading policies (~50%)
- OVS-DPDK, neutron (~900%)

Feature Name	First OpenStack* Release	Description	Benefit	Performance Data
Host CPU feature request	Icehouse*	Expose host CPU features to OpenStack managed guests	Guest can directly use CPU features instead of emulated CPU features	~20% to ~40% improvement in guest computation
PCI passthrough	Havana*	Provide direct access to a physical or virtual PCI device	Avoid the latencies introduced by hypervisor and virtual switching layers	~8% improvement in network throughput
HugePages* support	Kilo*	Use memory pages larger than the standard size	Fewer memory translations requiring fewer cycles	~10% to ~20% improvement in memory access speed
NUMA awareness	Juno*	Ensures virtual CPUs (vCPU)s executing processes and the memory used by these processes are on the same NUMA node	Ensures all memory accesses are local to the node and thus do not consume the limited cross-node memory bandwidth, adding latency to memory accesses	~10% improvement in guest processing
IO based NUMA scheduling	Kilo*	Creates an affinity that associates a VM with the same NUMA nodes as the PCI device passed into the VM	Delivers optimal performance when assigning PCI device to a guest	~25% improvement in network throughput for smaller packets
CPU pinning	Kilo	Supports the pinning of VMs to physical processors	Avoids scheduling mechanism moving the guest virtual CPUs to other host physical CPU cores, improving performance and determinism	~10 % to ~20% improvement in guest processing
CPU threading policies	Mitaka*	Provides control over how guests can use the host hyper thread siblings	More fine-grained deployment of guests on HT-enabled systems	Up to ~50% improvement in guest processing
OVS-DPDK, neutron	Liberty*	An industry standard virtual switch accelerated by DPDK	Accelerated virtual switching	~900% throughput improvement

출처: <https://software.intel.com/content/www/us/en/develop/articles/openstack-epa-feature-breakdown-and-analysis.html>

III. 응용 기술

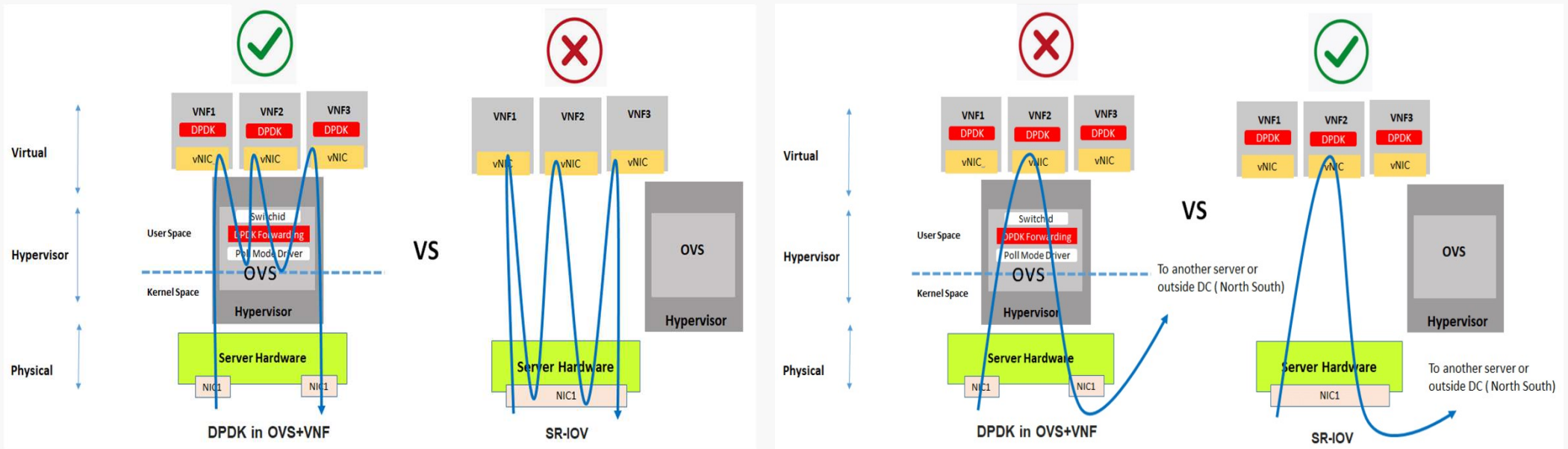
- ❑ HugePages* support
- ❑ NUMA awareness
- ❑ CPU pinning
- ❑ OVS-DPDK, neutron



출처: <https://superuser.openstack.org/articles/etsi-nfv-plugtests-vim/>

III. 응용 기술

- ❑ If Traffic is East-West, DPDK wins against SR-IOV
- ❑ If traffic is North-South, SR-IOV wins against DPDK



출처: https://telcocloudbridge.com/blog/dpdk-vs-sr-iov-for-nfv-why-a-wrong-decision-can-impact-performance/?fbclid=IwAR1LP9jcgZipbh5Hyrcq-kpheXwftJ_5KLP2hUIZJVaWwJ2TbDnqfqvHESk

III. 응용 기술

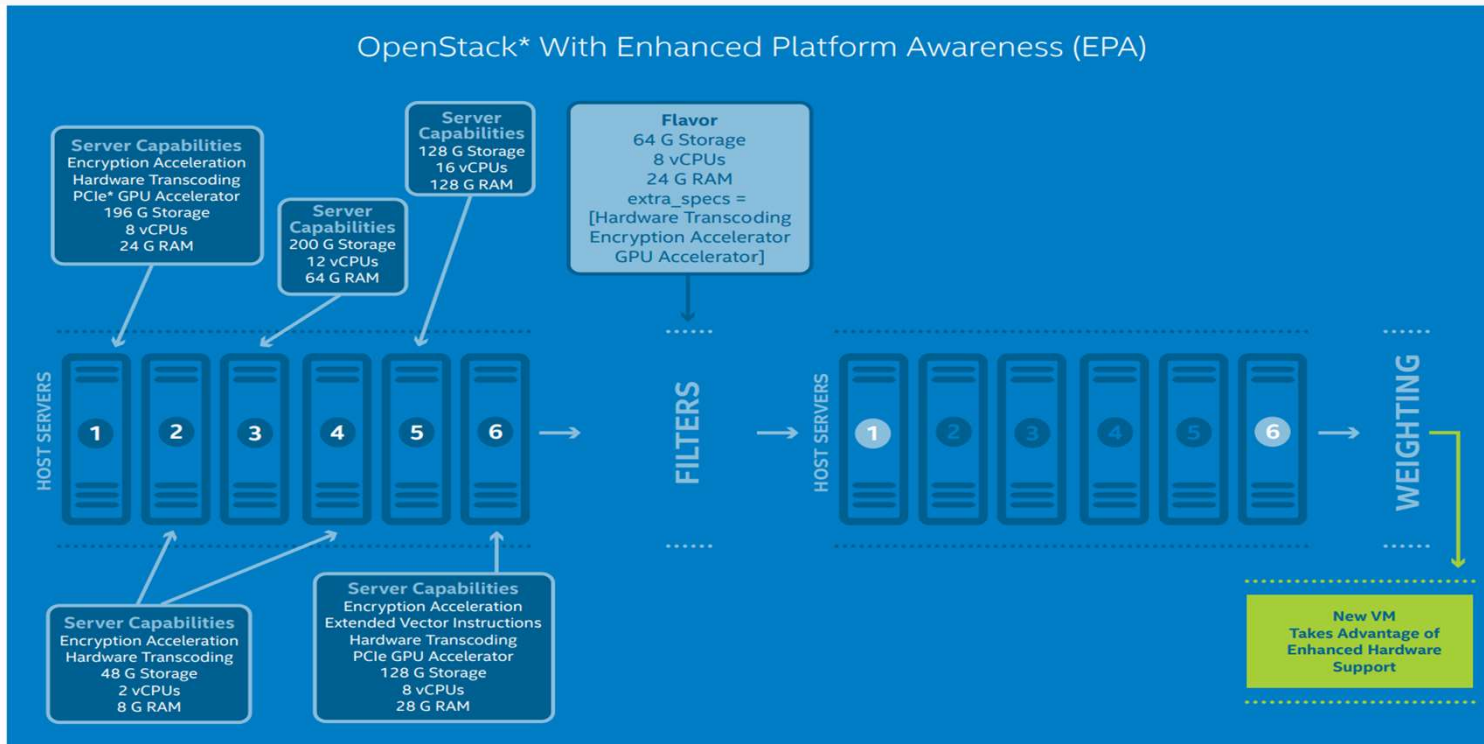
□ Enhanced Platform Awareness

	Enhanced with EPA			
	Accelerated SSL Security	Accelerated Floating-Point/ Integer Compute	Accelerated Encryption/ Compression for I/O	Accelerated Video Processing
What technology to specify in processors/ platforms	<ul style="list-style-type: none"> Intel® Advanced Encryption Standard New Instructions (Intel® AES – NI) 	<ul style="list-style-type: none"> Intel® Advanced Vector Extensions 2 (Intel® AVX2) 	<ul style="list-style-type: none"> Intel® QuickAssist Technology (in processors and add-on accelerator cards) 	<ul style="list-style-type: none"> Intel® Quick Sync Video
Intel products with the technology	<ul style="list-style-type: none"> Intel® Xeon® Processor E3 v3, E5 v3, and E7 v2 Families; Select Intel® Atom™ processors 	<ul style="list-style-type: none"> Intel® Xeon® processor E3 v3, E5 v3 Families Intel® Xeon® processor E7 v2 Family (supports Intel® AVX only) 	<ul style="list-style-type: none"> Intel® Xeon® Processor E5 2600, E5-2400 Families with Intel® Communications Chipset 89xx Series Intel® QuickAssist Adapter 8950 	<ul style="list-style-type: none"> Intel® Xeon® Processor E3 v3 Family
Use this filter	<ul style="list-style-type: none"> ComputeCapabilitiesFilter 		<ul style="list-style-type: none"> ComputeCapabilitiesFilter pci_passthrough_filter (for PCIe-based devices) 	<ul style="list-style-type: none"> ComputeCapabilitiesFilter
Workload must use the specific technology	Yes			
Specify the feature in the flavor	Yes			

출처: OpenStack Enhanced Platform Awareness – Enterprise Business (White Paper, Intel)

III. 응용 기술

- EPA(Enhanced Platform Awareness)는 Nova(노바) 스케줄러가 인스턴스 타입(Flavor)에 가능한 하드웨어에 배포



출처: OpenStack Enhanced Platform Awareness – Enterprise Business (White Paper, Intel)

III. 응용 기술

□ Configuring compute nodes to be EPA nodes

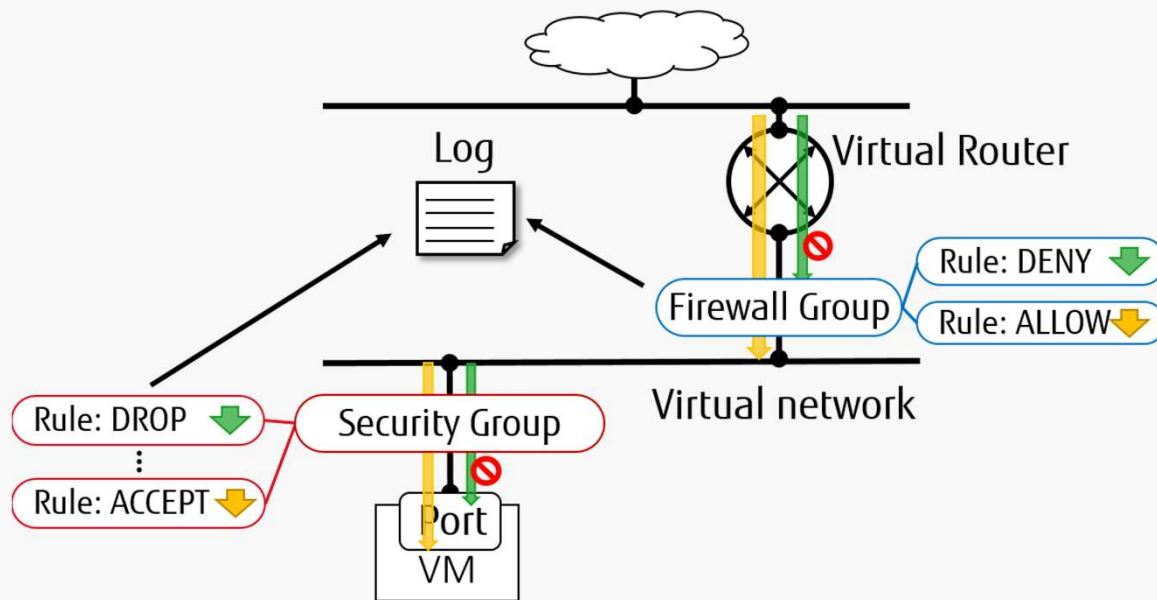
	BIOS	Hypervisor	OpenStack
NUMA Topology	X		X
SR-IOV	X	X	X
HyperThreading	X		
Huge Pages		X	
CPU Pinning		X	X

	nova.conf	ml2_conf.ini	ml2_conf_sriov.ini
NUMA Topology	X		
SR-IOV	X	X	X
CPU Pinning	X		

출처: https://docs.openstack.org/tacker/latest/user/enhanced_placement_awareness_usage_guide.html

III. 응용 기술

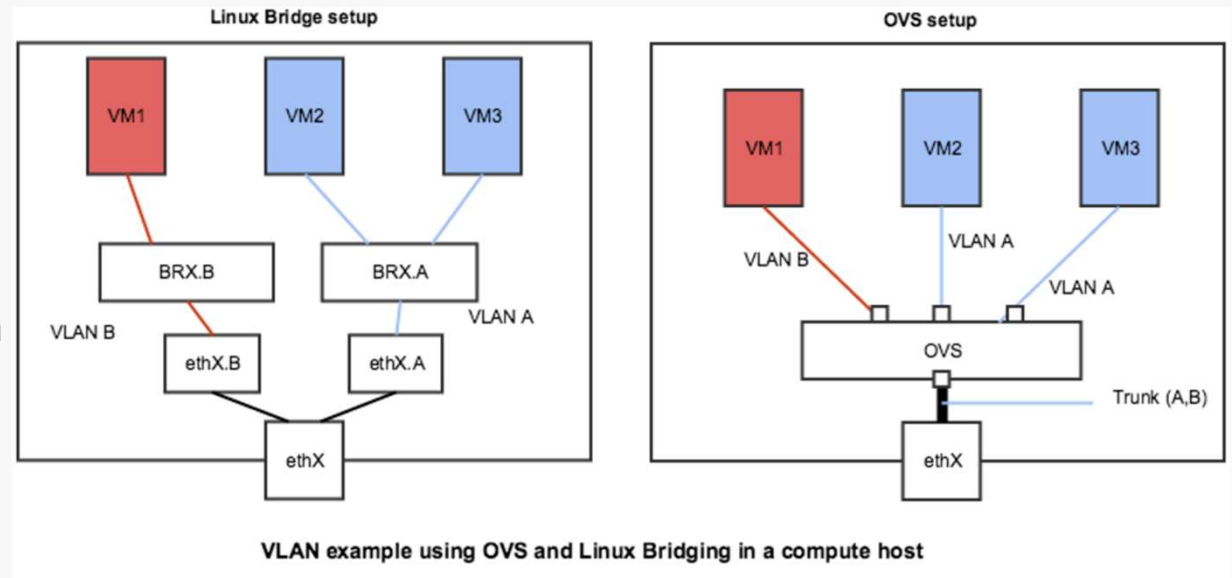
- ❑ Packet logging service is designed as a Neutron plug-in that captures network packets for relevant resources (e.g. security group or firewall group) when the registered events occur.



출처: <https://docs.openstack.org/neutron/rocky/admin/config-logging.html>

III. 응용 기술

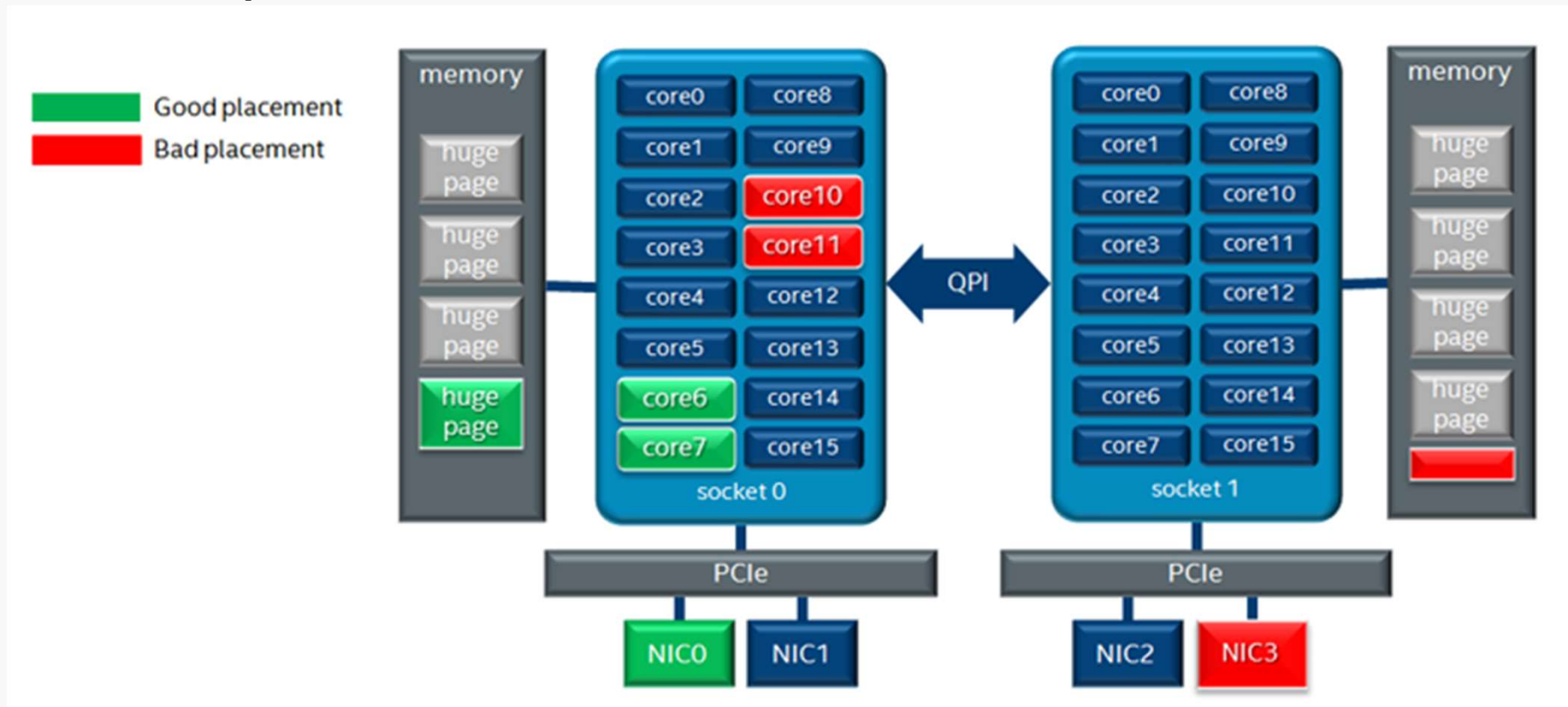
- ❑ Linux Bridge and OVS
- ❑ OpenStack Neutron
 - A Linux bridge is much more than just a virtual bridge. It also does filtering and traffic shaping. Also, you can program it to refer to IP tables before forwarding traffic using the bridge-netfilter module built into the Linux kernel.
 - On the other hand an Open vSwitch is an L2 virtual switch which allows programming flows conforming to OpenFlow standards and by design is inherently a distributed virtual switch.



출처: <https://platform9.com/blog/getting-started-openstack-neutron/>

III. 응용 기술

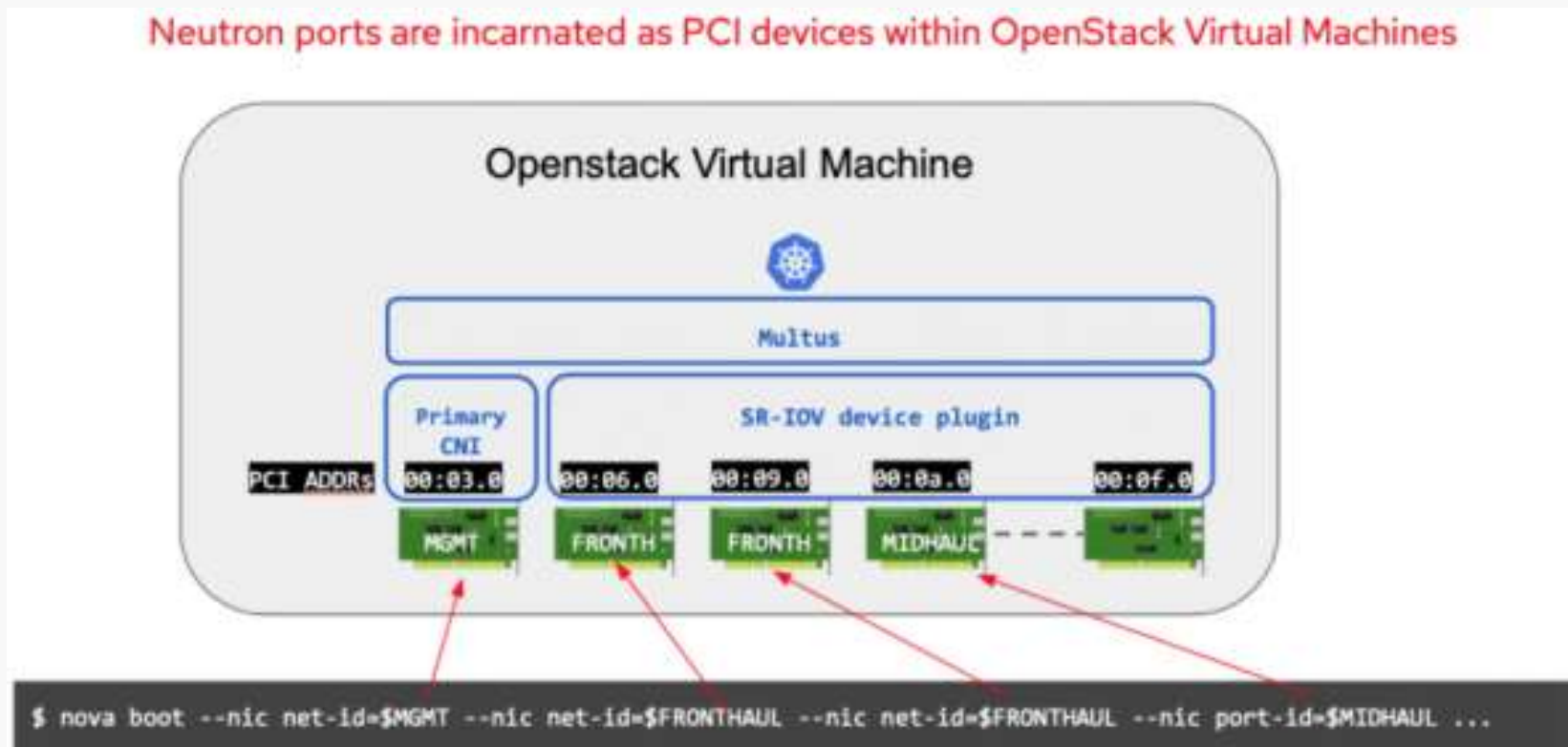
□ Guest NUMA placement considerations



출처: Guest NUMA placement considerations

III. 응용 기술

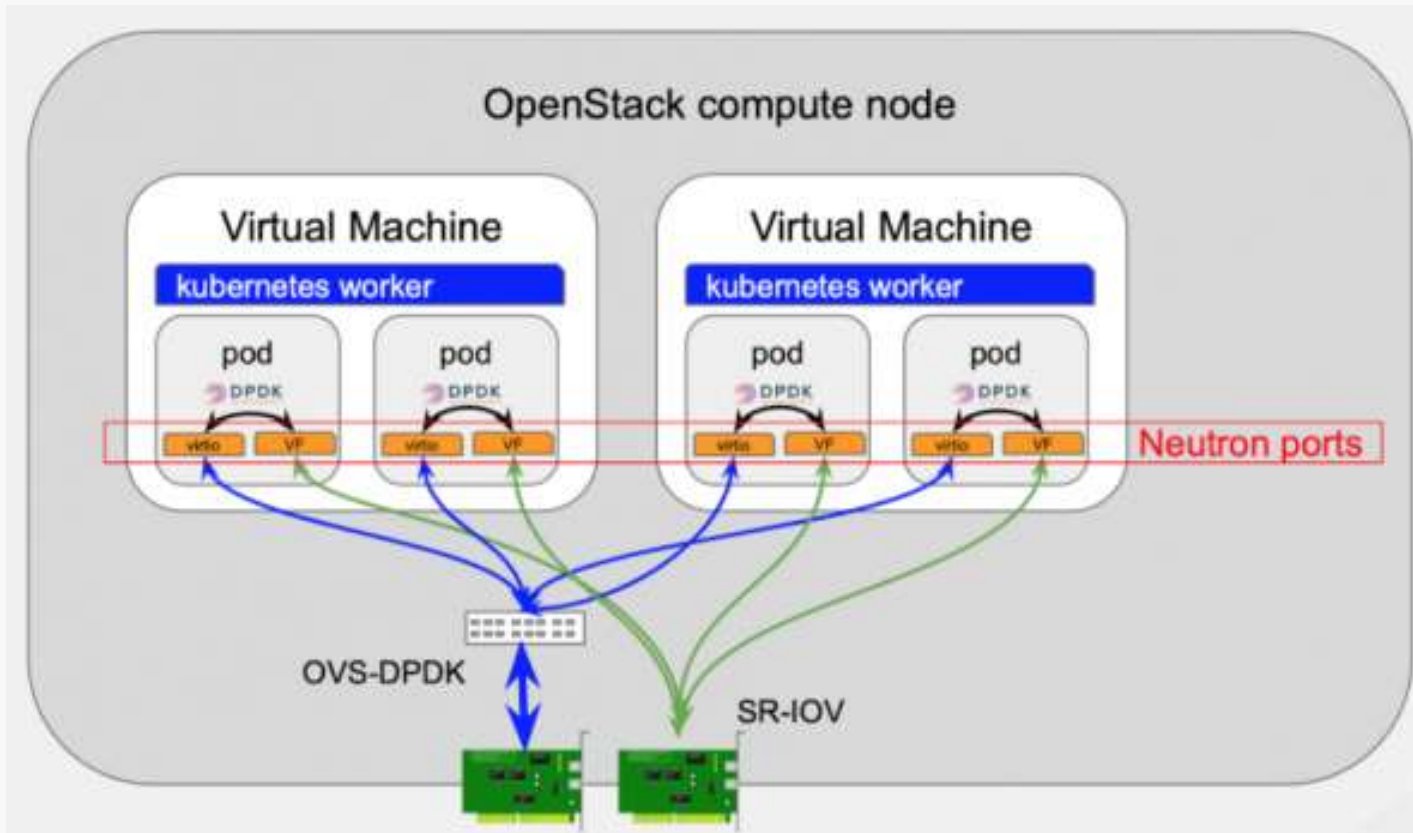
- Telco use cases – in particular 5G



출처: <https://superuser.openstack.org/articles/run-your-kubernetes-cluster-on-openstack-in-production/>

III. 응용 기술

- Telco use cases – in particular 5G



출처: <https://superuser.openstack.org/articles/run-your-kubernetes-cluster-on-openstack-in-production/>

III. 응용 기술

(1 of 3)

□ KubeVirt Networking

	Calico CNI	OpenStack Neutron
Network Model	Container Networking Model	VPC like Networking Model
Traffic Isolation	Not Support (tenant level)	VLAN, VXLAN, GRE, GENEVE
Provider Network	Not Support	FLAT
Container Network	Support	Not Support
Static IP Address	Not Support	Support
VM & Container Inter-connection	Not Support	Partially Support via Kuryr
Stateful Firewall	Partially Support via Network Policy	Support via Security Group
Load Balancer	Support	Support via Octavia
Acceleration	eBPF	OVS-DPDK, SR-IOV, PCI-PT

III. 응용 기술

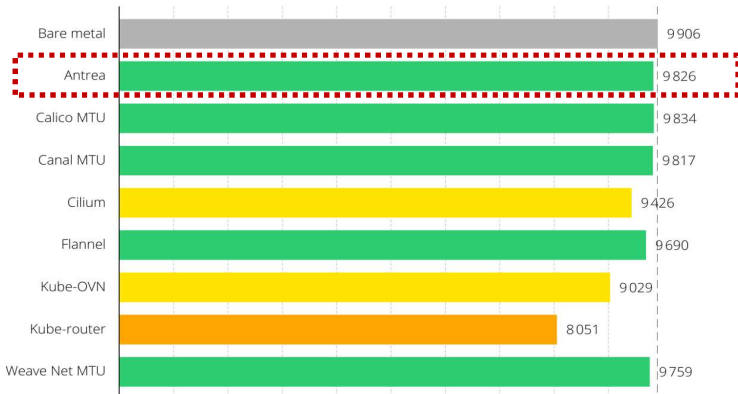
(2 of 3)

□ KubeVirt Networking

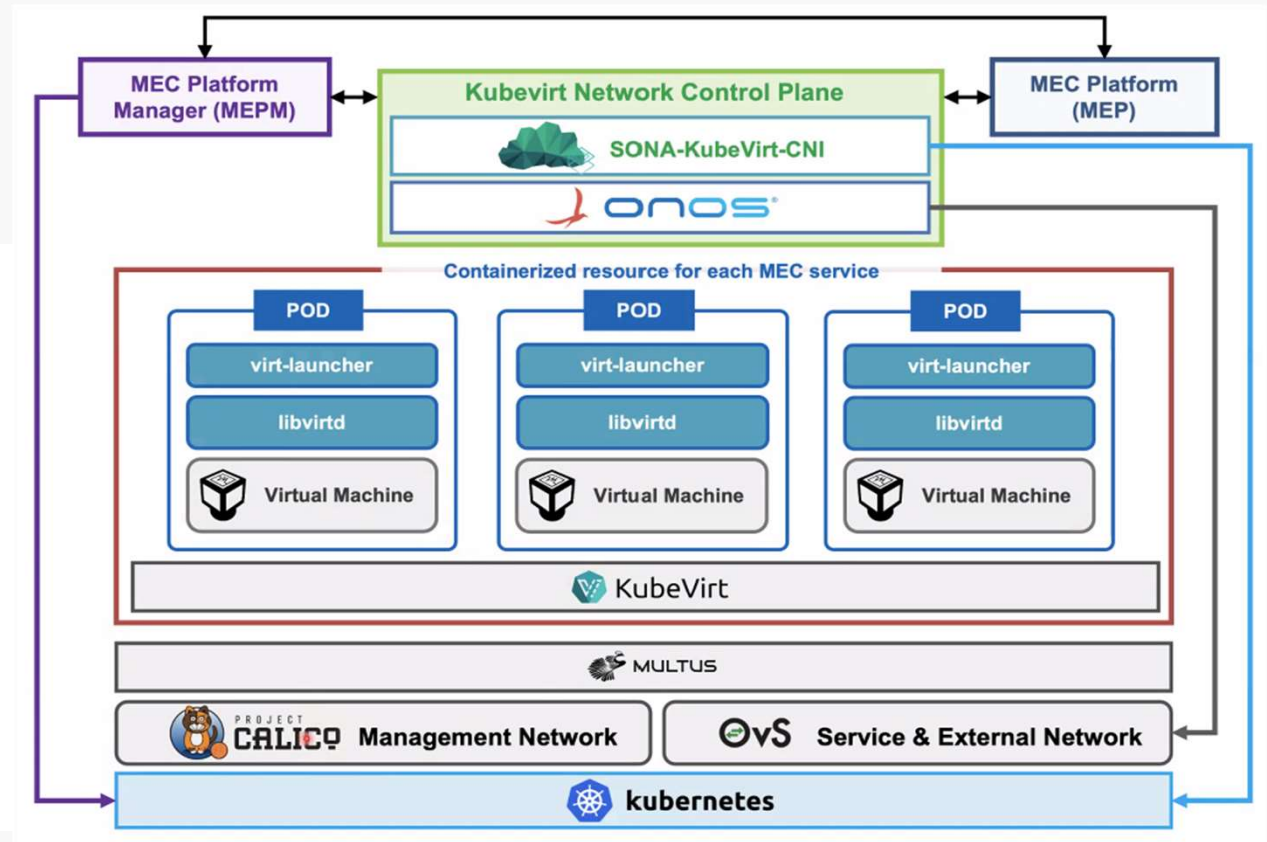
Antrea extends the benefit of programmable networks from Open vSwitch (OVS) to Kubernetes.

K8S CNI Benchmark - Pod to Pod - TCP - Bandwidth

CNI setup without any tuning



2020-08-27 - Alexis Ducastel - infrabuilder - Source : <https://github.com/InfraBuilder/benchmark-k8s-cni-2020-08>



출처: <https://itnext.io/benchmark-results-of-kubernetes-network-plugins-cni-over-10gbit-s-network-updated-august-2020-6e1b757b9e49>

III. 응용 기술

(3 of 3)

□ KubeVirt Networking

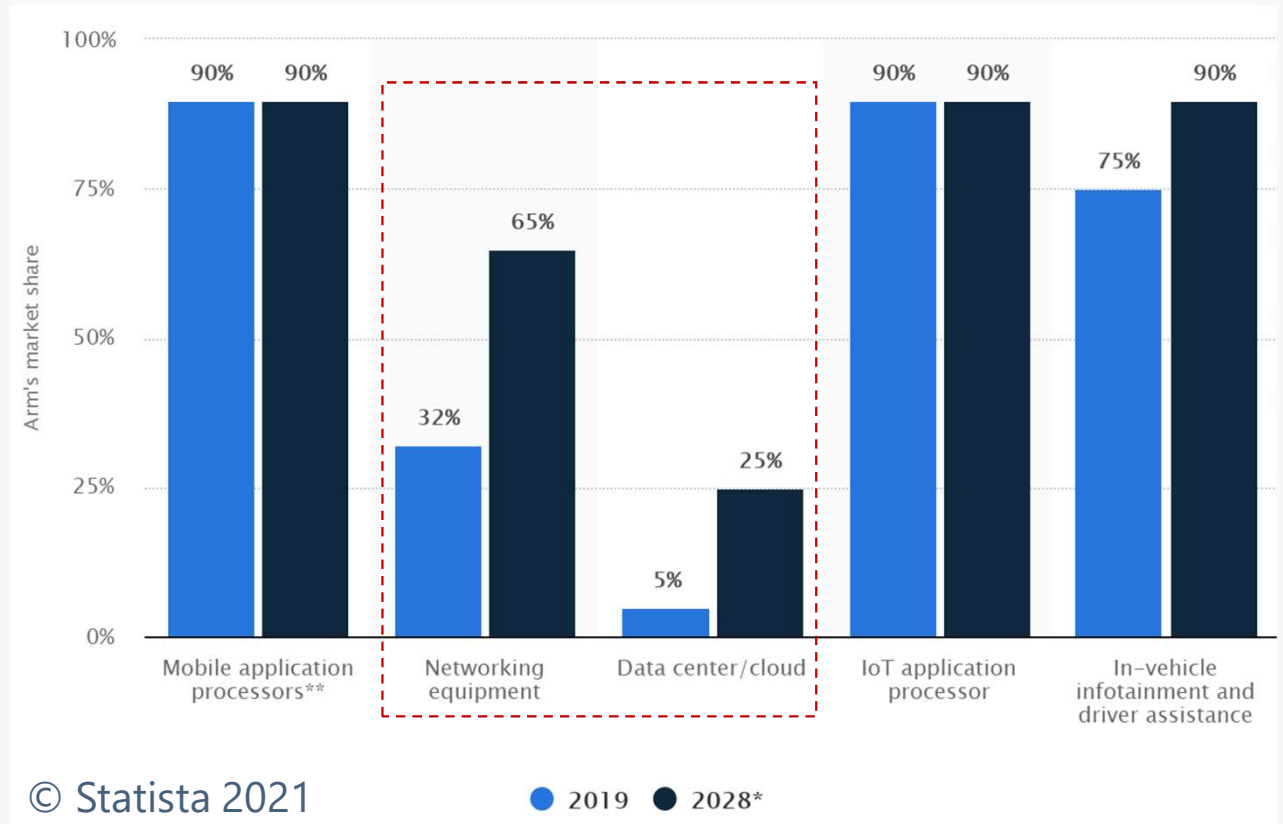
CNI Benchmark August 2020 infraBuilder	Config	Performances (bandwidth)				Resources consumption (cpu/ram)					Security features			
	MTU	Pod to Pod		Pod to Service		Idle	Pod to Pod		Pod to Service		Network Policies		Encryption	
	setting	TCP	UDP	TCP	UDP	none	TCP	UDP	TCP	UDP	in	out	activation	Performance
Antrea	auto	Very fast	Very fast	Very fast	Slow	Low	Low	Low	Low	Low	yes	yes	at deploy time	Slow
Calico	manual	Very fast	Very fast	Very fast	Fast	Low	Very low	Very low	Very low	Very low	yes	yes	anytime	Very fast
Canal	manual	Very fast	Very fast	Very fast	Very fast	Low	Very low	Very low	Very low	Very low	yes	yes	no	n/a
Cilium	auto	Fast	Very fast	Very fast	Very fast	High	High	High	High	High	yes	yes	at deploy time	Slow
Flannel	auto	Very fast	Very fast	Very fast	Very fast	Very low	Very low	Very low	Very low	Very low	no	no	no	n/a
Kube-OVN	auto	Fast	Very slow	Fast	Very slow	High	High	High	High	High	yes	yes	no	n/a
Kube-router	none	Slow	Very slow	Slow	Very slow	Low	Very low	Low	Very low	Low	yes	yes	no	n/a
Weave Net	manual	Very fast	Very fast	Very fast	Fast	Very low	Low	Low	Low	Low	yes	yes	at deploy time	Slow

출처: <https://itnext.io/benchmark-results-of-kubernetes-network-plugins-cni-over-10gbit-s-network-updated-august-2020-6e1b757b9e49>

III. 응용 기술

- Arm's market share and targets across key technology markets in 2019 and 2028 fiscal years
- Data center / cloud 5%(2019) → 25%(2028)

OpenStack
Ubuntu
ARM



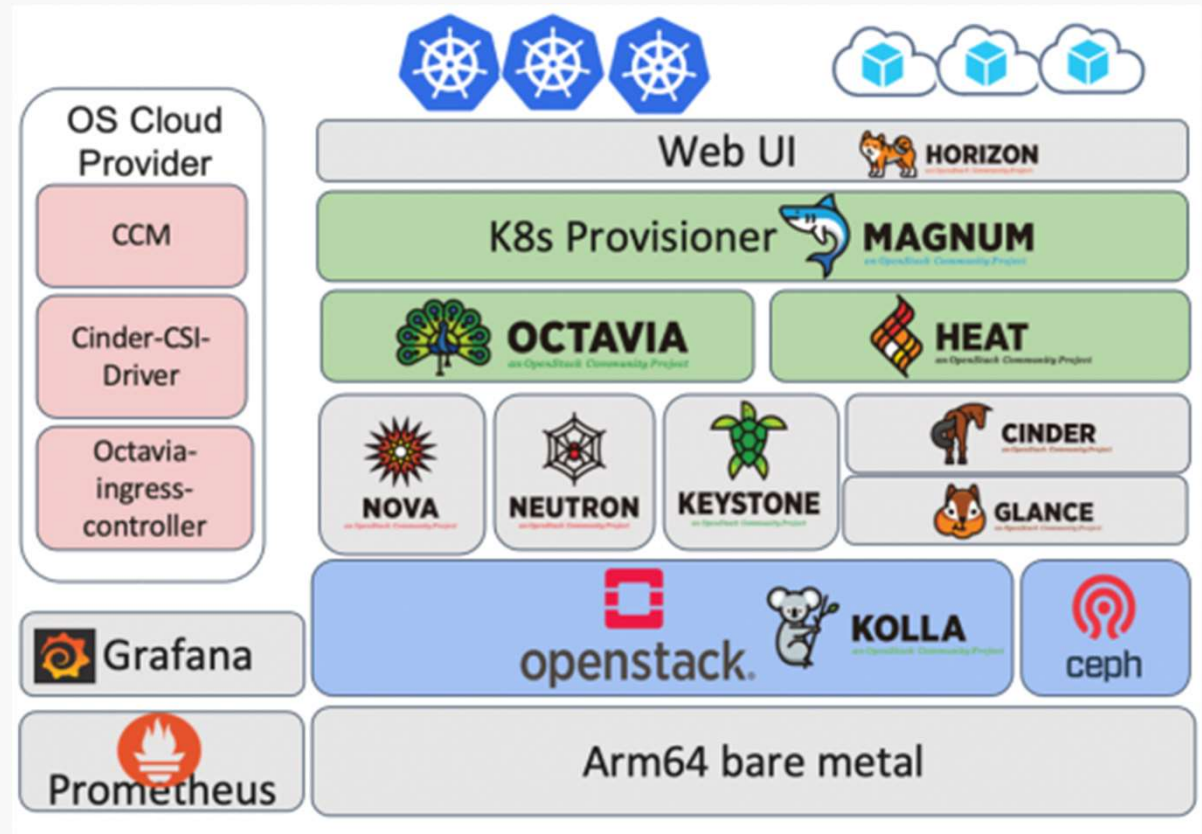
출처: <https://www.statista.com/statistics/1132112/arm-market-share-targets/>

참고: <https://selfish-developer.com/entry/KVM-ARM>

III. 응용 기술

- Nova/Ironic/disk-image-builder enablement and bugfix on ARM64
- Devstack enablement support for ARM64 OpenStack
- Kolla image build, Kolla-ansible deployment support, and bugfix for OpenStack version upgrading.
- Magnum multi-arch support and K8s cloud provider support on ARM64

EasyStack, there are nearly 30 customers in total, with more than 500 cloud computing physical nodes based on Arm architecture are used in production and run well, among which the longest-running customers are more than one year.



출처: <https://superuser.openstack.org/articles/the-progress-for-cloud-computing-on-arm-architecture/> (February 24, 2021)

IV. 기업을 위한 Telco Cloud

- ❑ ONF의 기업용 5G 특화망 (Private 5G)
- ❑ Aether
- ❑ 5G Open Test Lab

IV. 기업을 위한 Telco Cloud

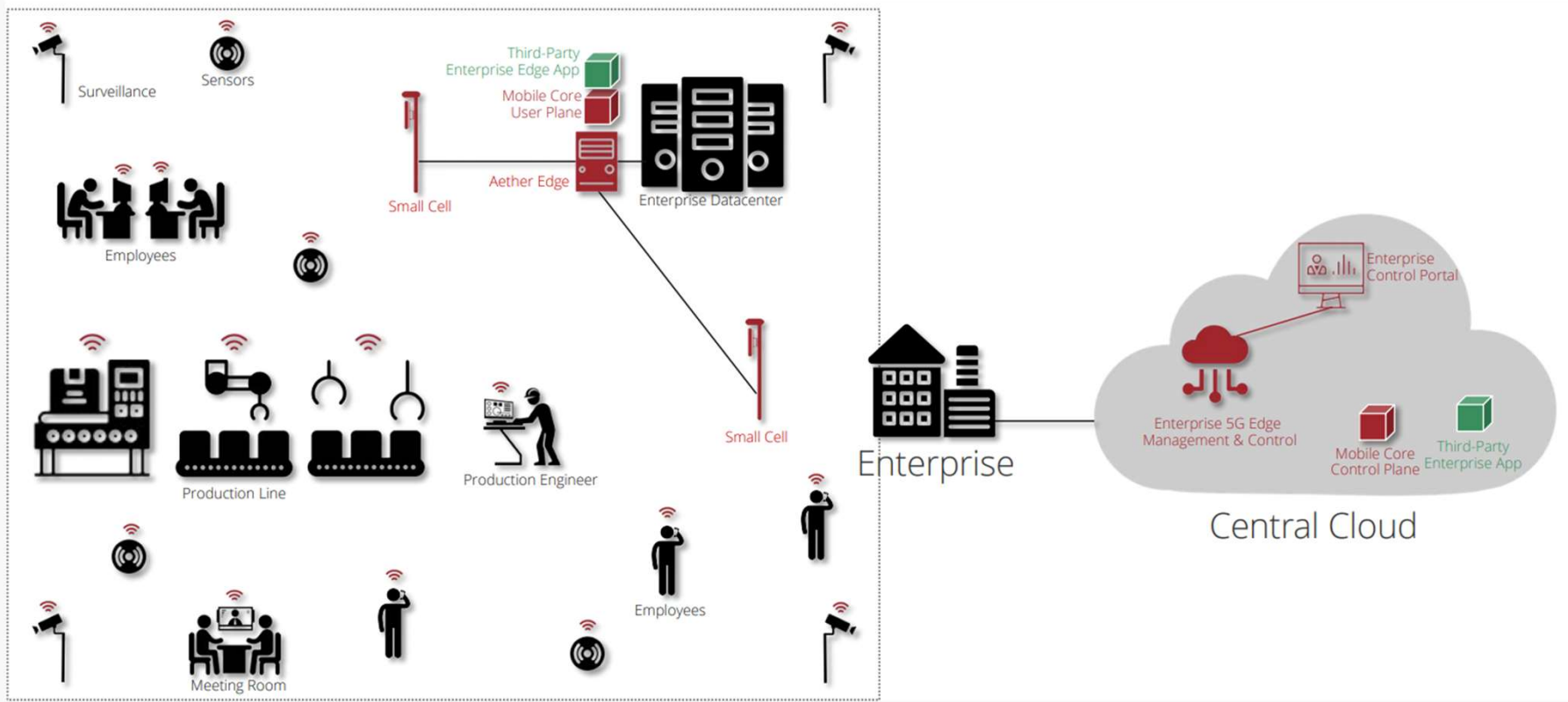
- ONF의 기업용 5G 특화망 (Private 5G)
 - Project: Aether



출처: <https://opennetworking.org/news-and-events/press-releases/onf-announces-new-sd-fabric-project-an-open-source-full-stack-programmable-network-fabric-for-hybrid-cloud-edge-cloud-5g-and-industrial-iot/>

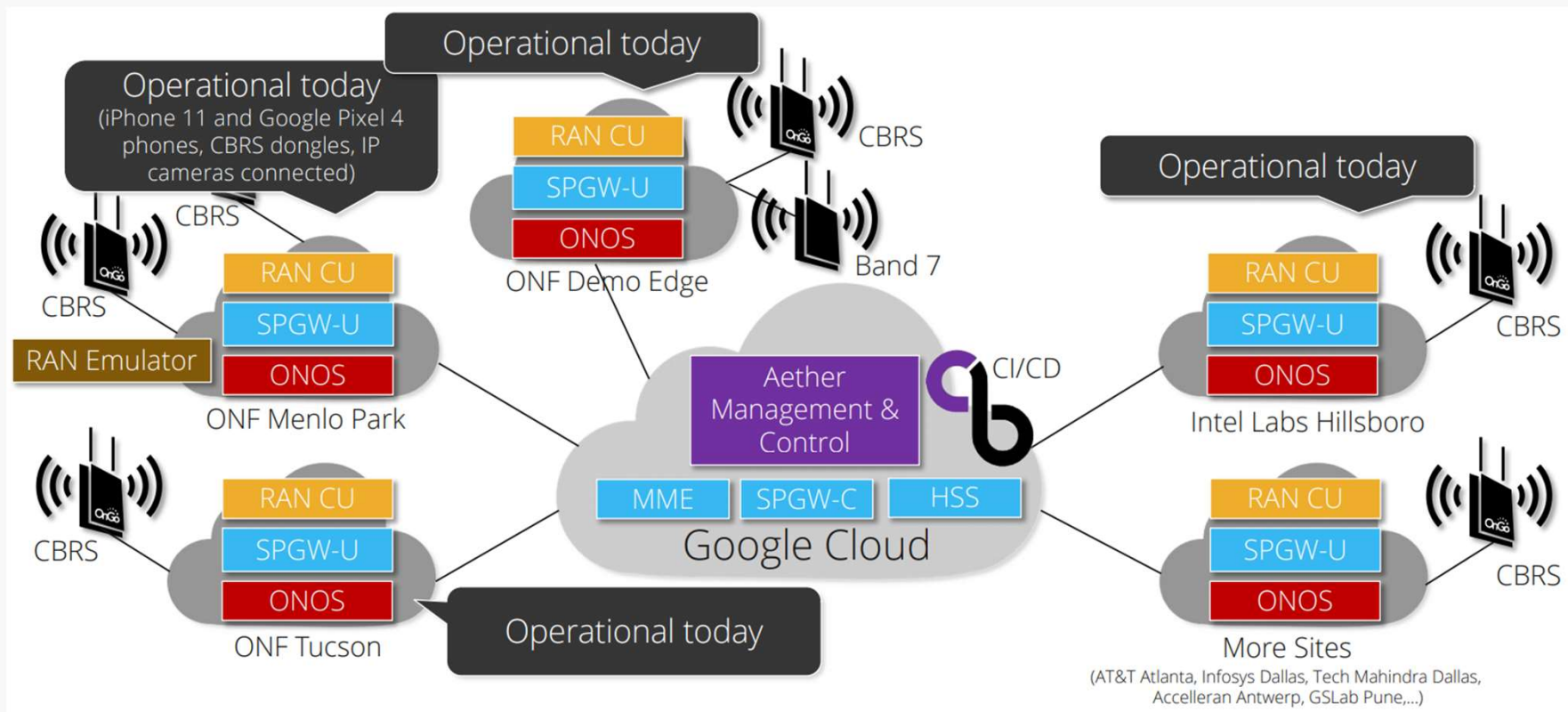
IV. 기업을 위한 Telco Cloud

□ Aether: Enterprise-5G/LTE-Edge-Cloud-as-a-Service



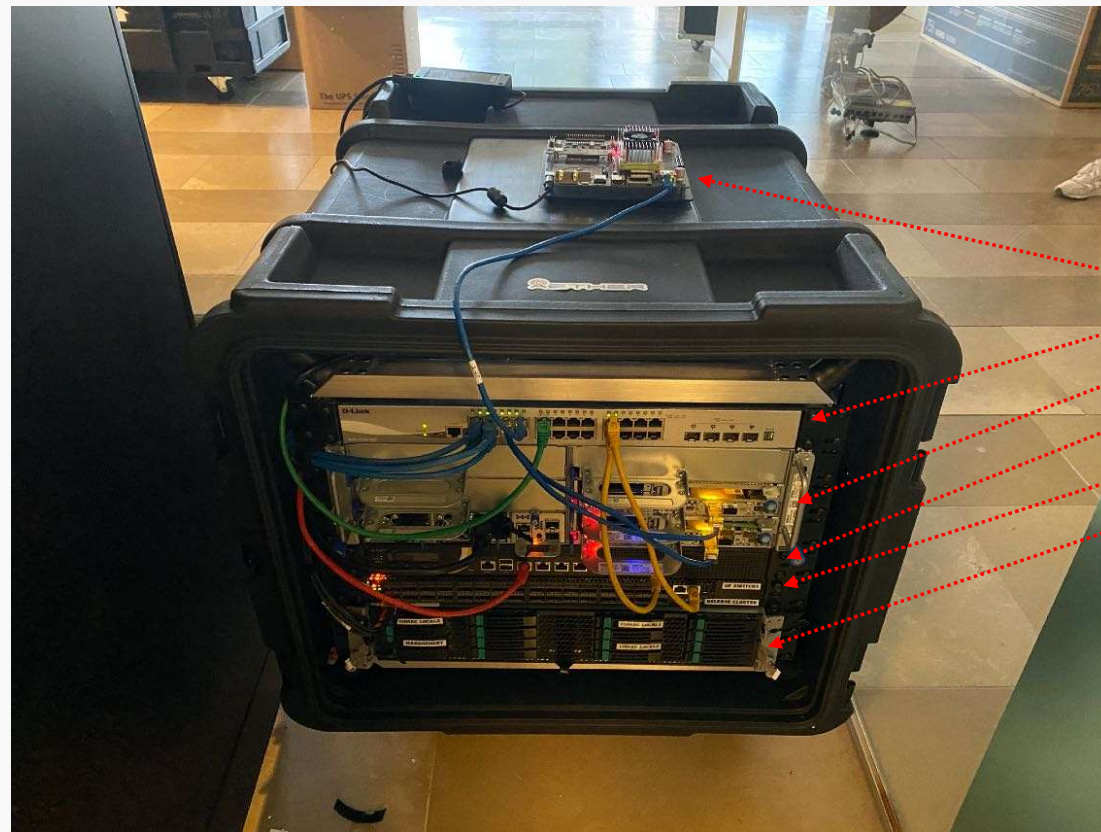
IV. 기업을 위한 Telco Cloud

□ Aether is operational today



IV. 기업을 위한 Telco Cloud

□ Aether Edge



ONF

- GPU Kit
- Management Switch
- OCP Servers
- VPN Router
- OpenFlow Switch
- COTS

IV. 기업을 위한 Telco Cloud

□ Aether Connectivity

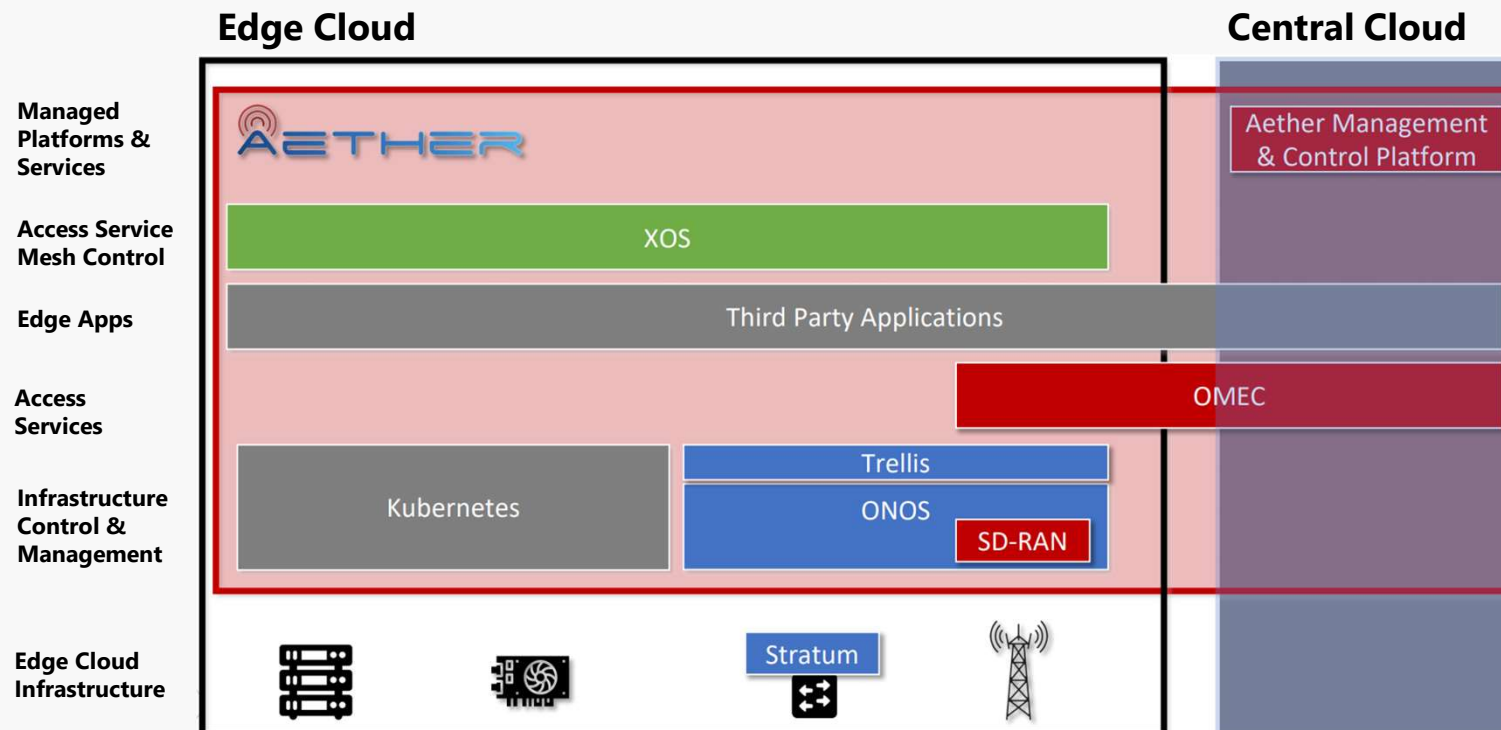


ONF

- CBRS Small Cell (Sercom, Accelleran)
- Band 7 Small Cell (Accelleran)
- CBRS Handset (iPhone 11, Google Pixel 4)
- Band 7 Handset (Samsung)

IV. 기업을 위한 Telco Cloud

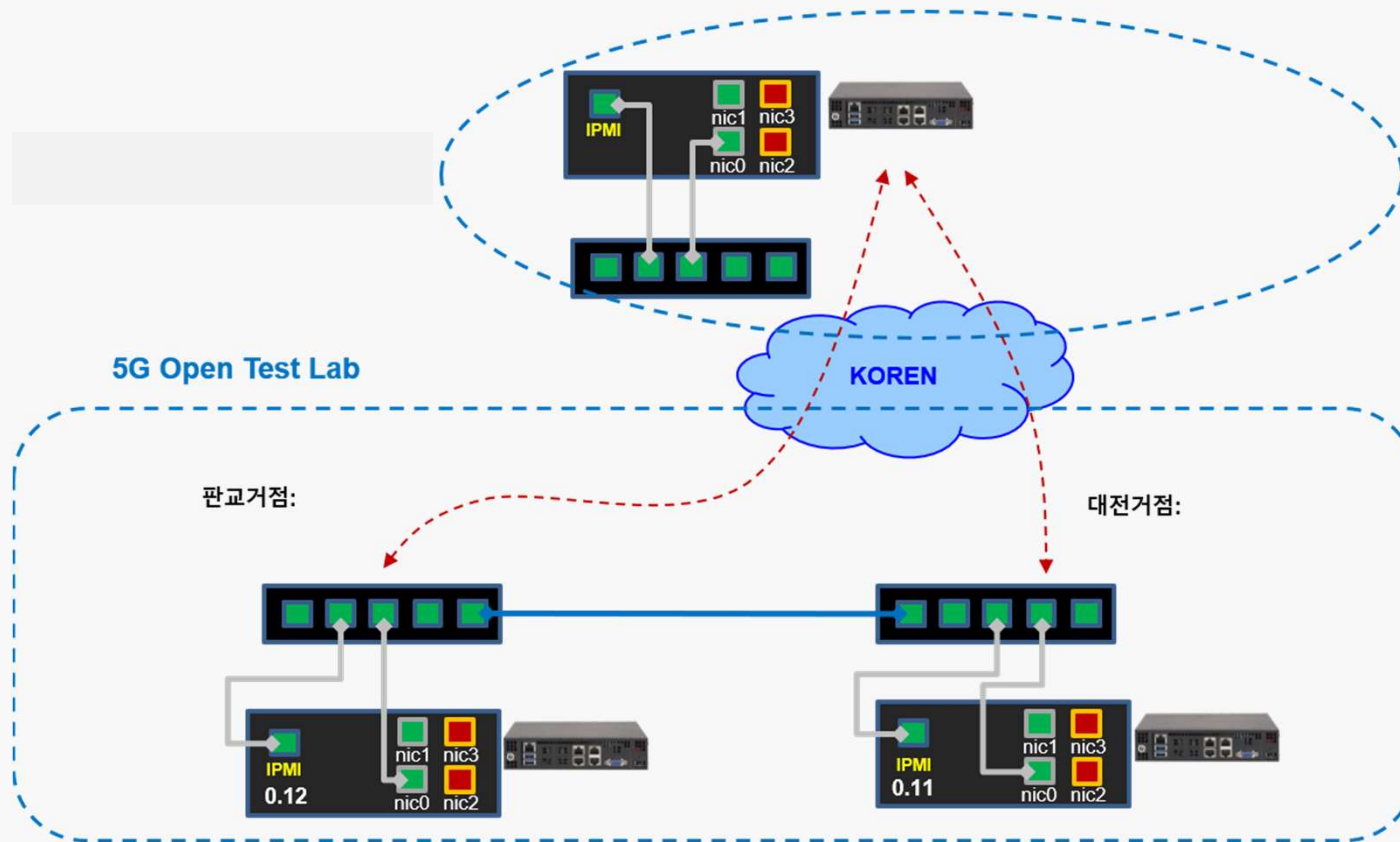
- ❑ Aether (ONF projects)
- ❑ Enterprise-5G/LTE-Edge-Cloud-as-a-Service



출처: <https://www.opennetworking.org/aether/>

IV. 기업을 위한 Telco Cloud

□ 5G Open Test Lab



감사합니다.

