

# KREONET SOFTWAREIZATION

**KREONET-S Updates: ONOS 기반 SDN-centric WAN 구축 및  
가상화/지능화 기술개발 현황**

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**November 6, 2019**

**Open Networking Korea 2019 Fall**

# Contents

- KREONET-S Status Updates
- Network Virtualization and Intelligence Development over KREONET-S
- Conclusion

# KREONET: NREN in Korea

« Nationwide 17 GigaPoPs in Korea (~100Gbps), 4 International Connections to the US, China, Europe (~100Gbps), Global Research Network Collaborations (GLORIAD, GLIF/GNA-G, GRP, etc.), ~200 member institutions, Supercomputing/Advanced Science Applications »

\*\*\* 24 x 7 Network Operations Center \*\*\*



**KREONETS: Open, Virtualized, Intelligent, and Automated Network Environment**  
migrated from Hardware-based, Fixed, Closed Network Infra & Services

KREONET & GLORIAD



# KREONET-S (KREONET Softwarization)

- **Roles and Goals**

- Nation-wide and International **SDN-WAN Environment for Advanced R&E Community** over KREONET in Korea
- New User Services & Experiences beyond Legacy Networking, based on **Virtually Dedicated Networking and Orchestrations**

- **Principal Building Blocks**

- Infrastructure/SBI: **OpenFlow 1.3**, Stratum/P4, TLI, NETCONF, etc.
  - 8 Locations: **SEO, DJ, BS, GJ, CW** (Korea), **Chicago** (USA), **Seattle** (USA), **HK** (China)
- Control/Distributed Core: **ONOS 1.13.1** (Nightingale Release)
  - KISTI as **ONF/ONOS** collaborator, ambassador and brigade member, **ONOS/CORD WG** member@SDN/NFV Forum in Korea
- Virtualization & Orchestration/NBI: **VDN 1.1.5**, **VDNO 1.0**

# KREONET-S Development Status

## Openflow 1.3 기반 SDN 광역망 네트워크 인프라

- > 국내 5개 망센터: 대전, 서울, 부산, 광주, 창원
- > 국제 3개 망센터: 미국/시카고, 미국/시애틀, 중국/홍콩

## Carrier-Grade SDN 컨트롤러 ONOS 기반 네트워크 제어

- > ONOS 기반 분산 제어 플랫폼 운영 [3/5-인스턴스]
- > 고가용성, 확장성, 프로그래머블 네트워크 제공

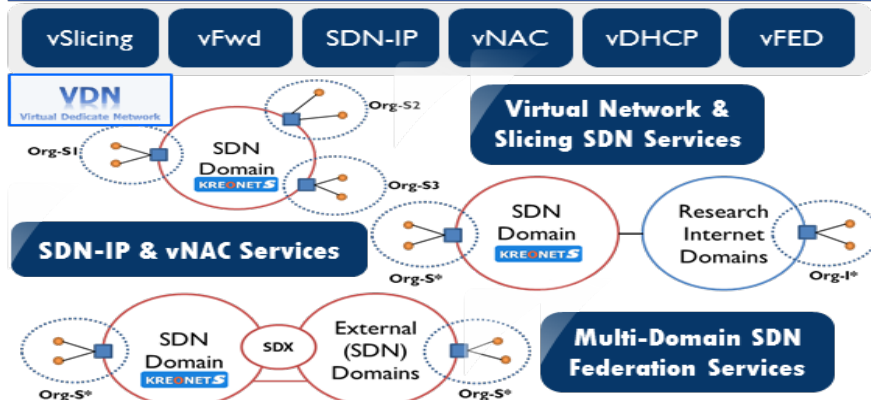
가상전용네트워킹(VDN) 기반  
高性能/高대역/高보안성 제공

- > 가상망 동적 대역폭 할당/제어 및 독립적/배타적 데이터 전송 서비스
- > SDN-IP 및 가상망 접근 제어 서비스
- > 다중 SDN 망 페더레이션 서비스

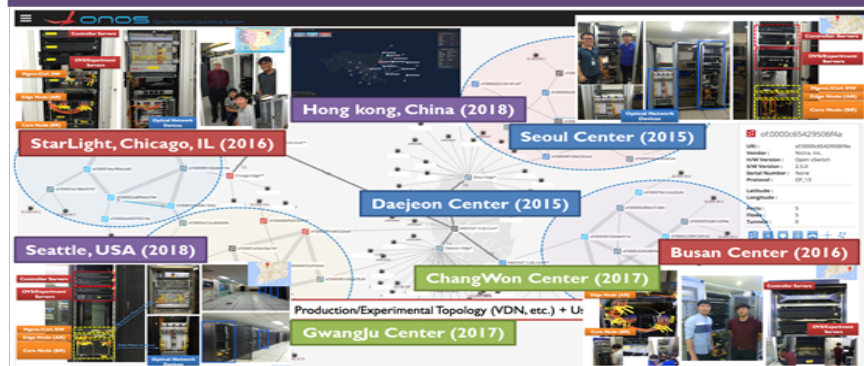
## KREONET-S 서비스 지능화 /자동화 오케스트레이션(NI)

- > 물리/가상 자원과 네트워킹의 융합 최적화/지능화 프로비저닝
- > AI/ML 기반 가상 네트워크 관리
- > 소프트웨어기반 자율 네트워킹 환경

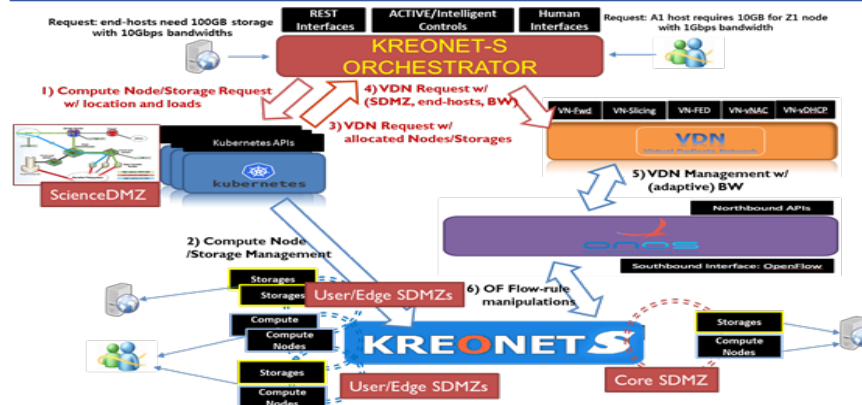
## KREONET-S Virtualization & Service (VDN)



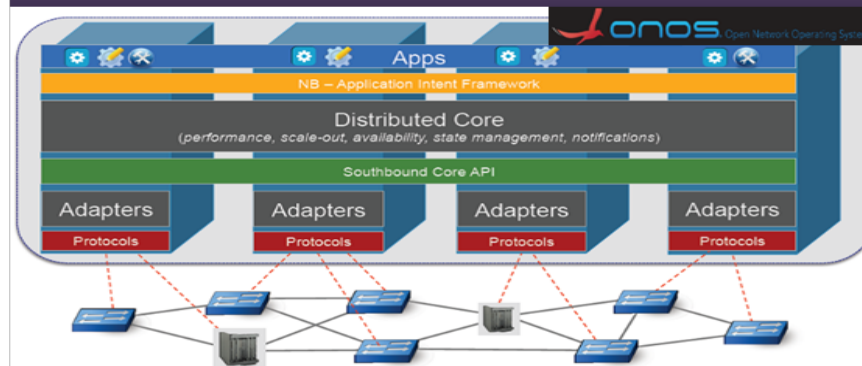
## KREONET-S/SDN Data Plane



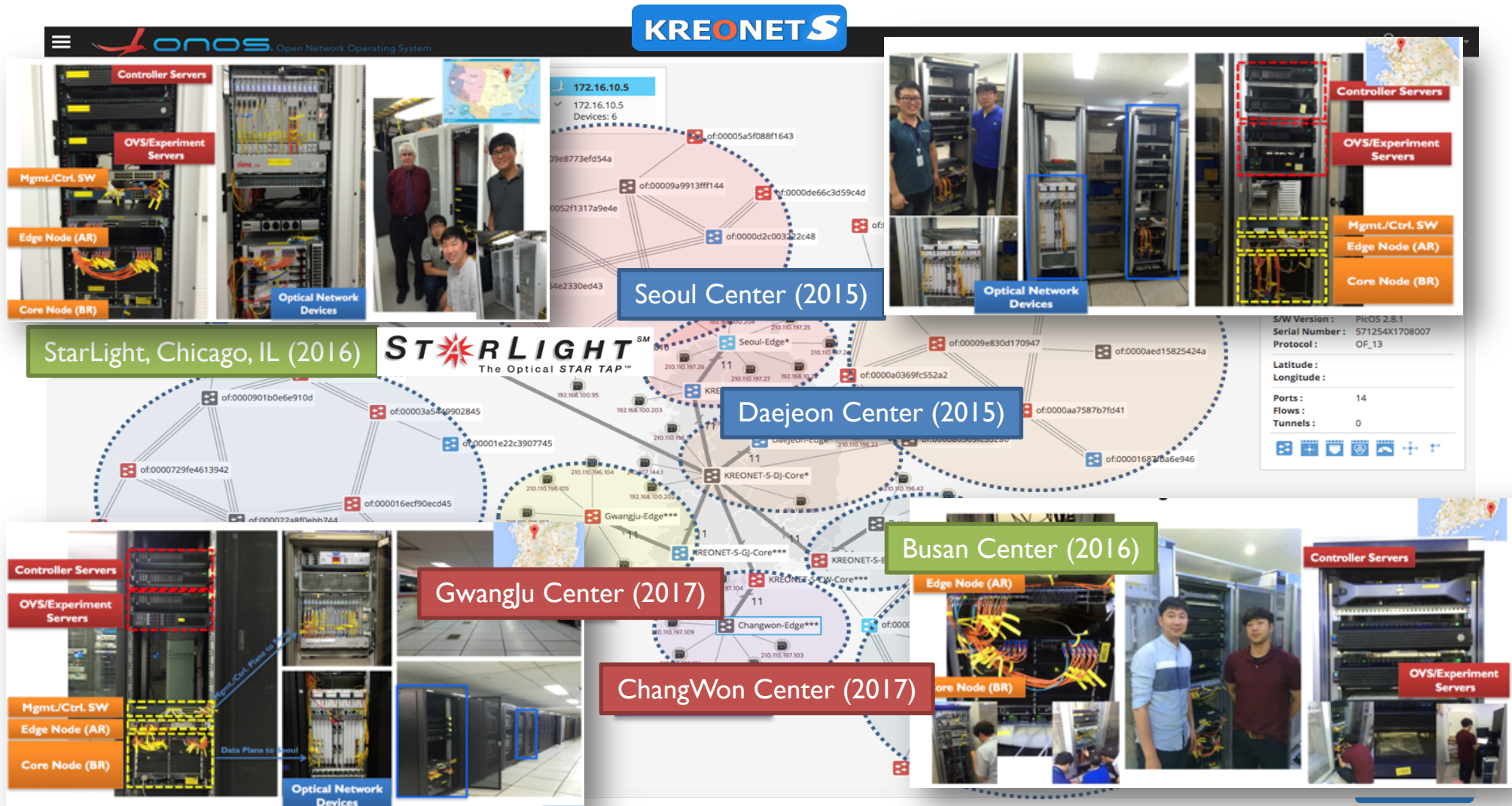
## KREONET-S Orchestration & intelligence (NI)



## KREONET-S/SDN Control Plane



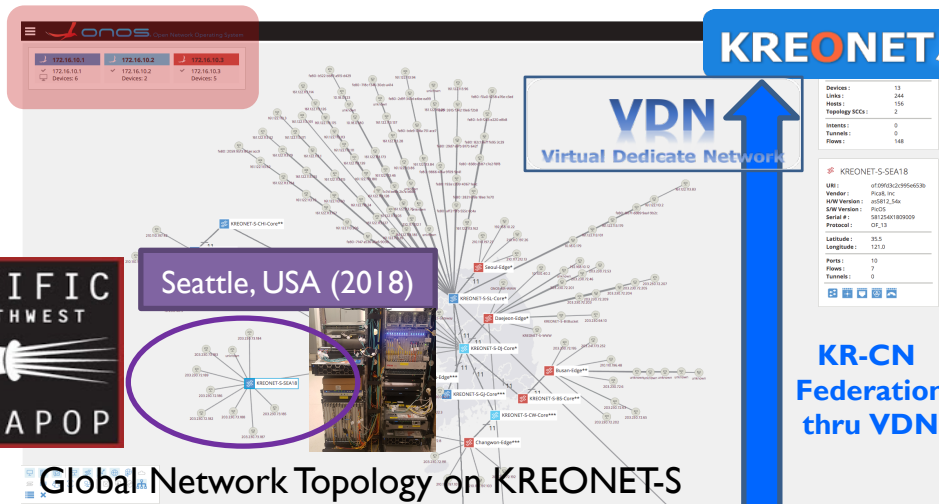
- 2015-2017 : Deployment in Six Locations in Korea and USA



# KREONET-S Infrastructure (2)

- 2018-2019 : Deployed in Two more Locations in USA and China
  - VDN Federation: Two Individual SDN Domains in KR and CN

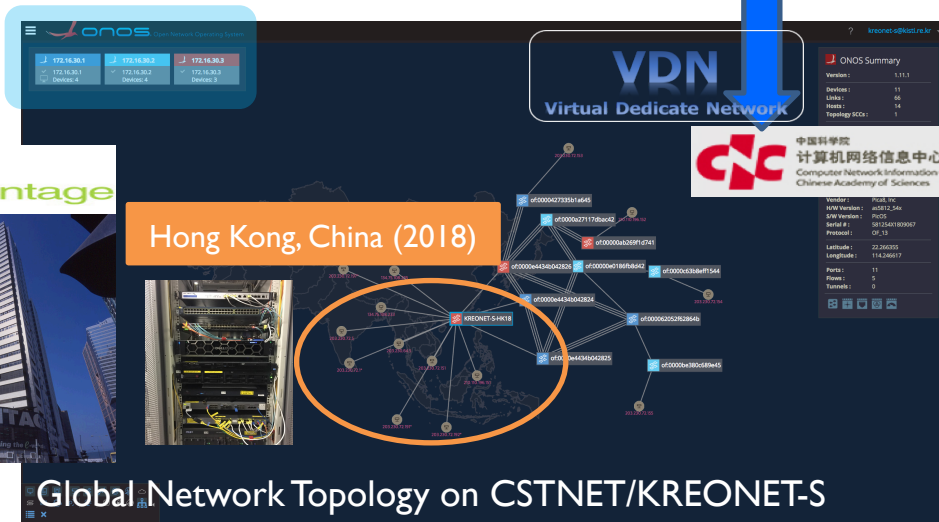
KREONET-S  
SDN Domain



Seattle, USA (2018)



CST-Cloud  
SDN Domain



Hong Kong, China (2018)

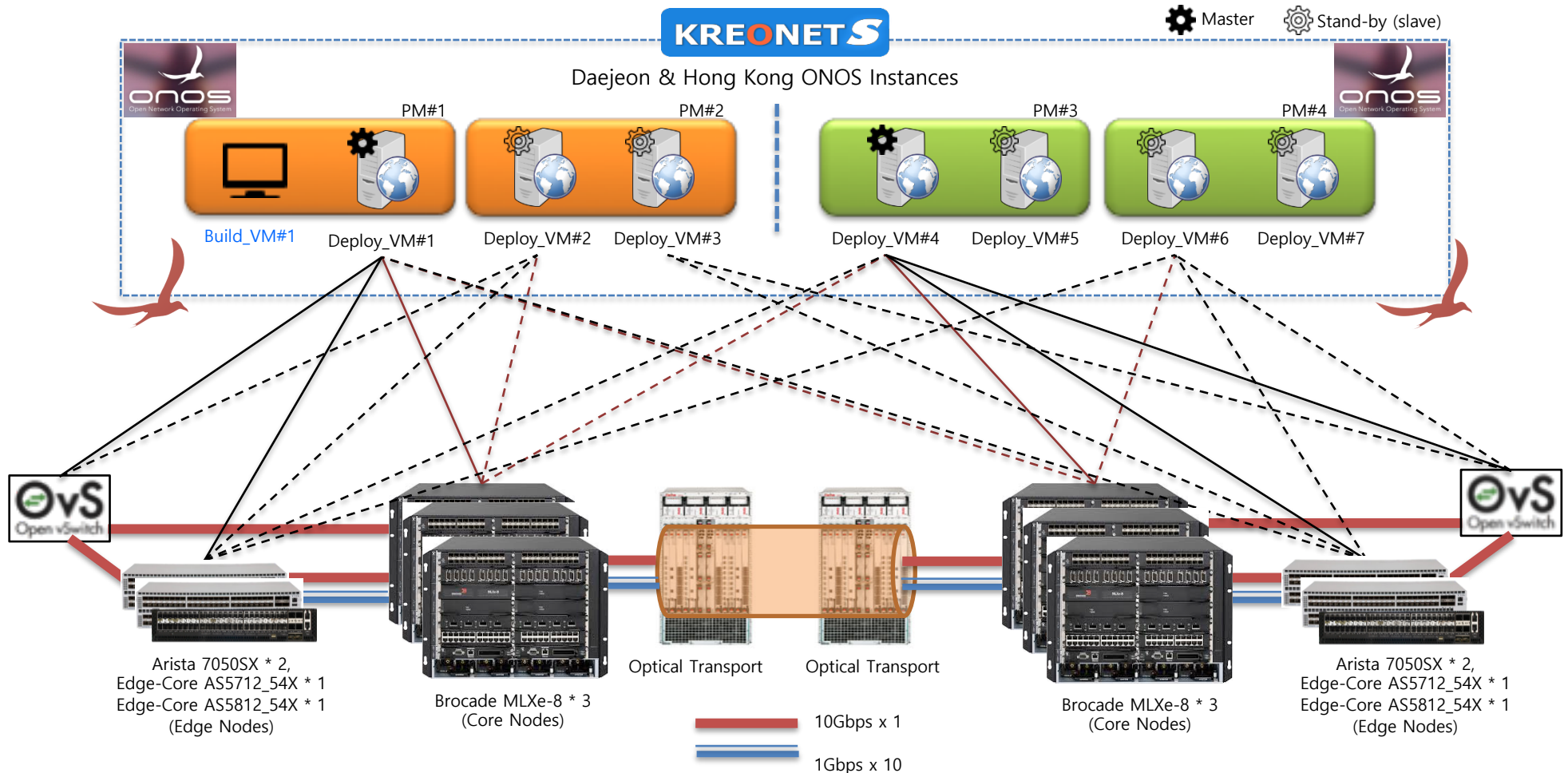


```
[root@localhost ~]# ping 203.230.72.191
PING 203.230.72.191 (203.230.72.191) 56(84) bytes of data.
64 bytes from 203.230.72.191: icmp_seq=1 ttl=64 time=47.4 ms
64 bytes from 203.230.72.191: icmp_seq=2 ttl=64 time=37.0 ms
64 bytes from 203.230.72.191: icmp_seq=3 ttl=64 time=33.4 ms
^C
--- 203.230.72.191 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2010ms
rtt min/avg/max/mdev = 37.022/139.515/334.051/137.624 ms
[root@localhost ~]# ping 203.230.72.192
PING 203.230.72.192 (203.230.72.192) 56(84) bytes of data.
64 bytes from 203.230.72.192: icmp_seq=1 ttl=64 time=84.8 ms
64 bytes from 203.230.72.192: icmp_seq=2 ttl=64 time=47.1 ms
64 bytes from 203.230.72.192: icmp_seq=3 ttl=64 time=73.4 ms
64 bytes from 203.230.72.192: icmp_seq=4 ttl=64 time=37.0 ms
^C
--- 203.230.72.192 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3018ms
rtt min/avg/max/mdev = 37.033/251.448/848.175/344.776 ms
[root@localhost ~]# ping 203.230.72.197
PING 203.230.72.197 (203.230.72.197) 56(84) bytes of data.
64 bytes from 203.230.72.197: icmp_seq=1 ttl=64 time=184 ms
64 bytes from 203.230.72.197: icmp_seq=2 ttl=64 time=33.5 ms
^C
```

```
PING 203.230.72.151 (203.230.72.151) 56(84) bytes of data.
64 bytes from 203.230.72.151: icmp_seq=1 ttl=64 time=997 ms
64 bytes from 203.230.72.151: icmp_seq=2 ttl=64 time=36.8 ms
64 bytes from 203.230.72.151: icmp_seq=3 ttl=64 time=37.5 ms
^C
--- 203.230.72.151 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2000ms
rtt min/avg/max/mdev = 36.842/357.408/997.793/452.820 ms
[root@localhost ~]# ping 203.230.72.154
PING 203.230.72.154 (203.230.72.154) 56(84) bytes of data.
64 bytes from 203.230.72.154: icmp_seq=1 ttl=64 time=974 ms
64 bytes from 203.230.72.154: icmp_seq=2 ttl=64 time=64.9 ms
64 bytes from 203.230.72.154: icmp_seq=3 ttl=64 time=71.8 ms
64 bytes from 203.230.72.154: icmp_seq=4 ttl=64 time=33.7 ms
^C
--- 203.230.72.154 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3013ms
rtt min/avg/max/mdev = 33.744/286.323/974.792/397.746 ms
[root@localhost ~]# ping 203.230.72.155
PING 203.230.72.155 (203.230.72.155) 56(84) bytes of data.
64 bytes from 203.230.72.155: icmp_seq=1 ttl=64 time=524 ms
64 bytes from 203.230.72.155: icmp_seq=2 ttl=64 time=61.7 ms
64 bytes from 203.230.72.155: icmp_seq=3 ttl=64 time=62.2 ms
^C
```

# KREONET-S Control Layer

- 3-node ONOS Cluster, v1.13.1 Nightingale Release (KR-US Domain)
- 3-node ONOS Cluster, v1.11.1 Loon Release (CN/HK Domain)

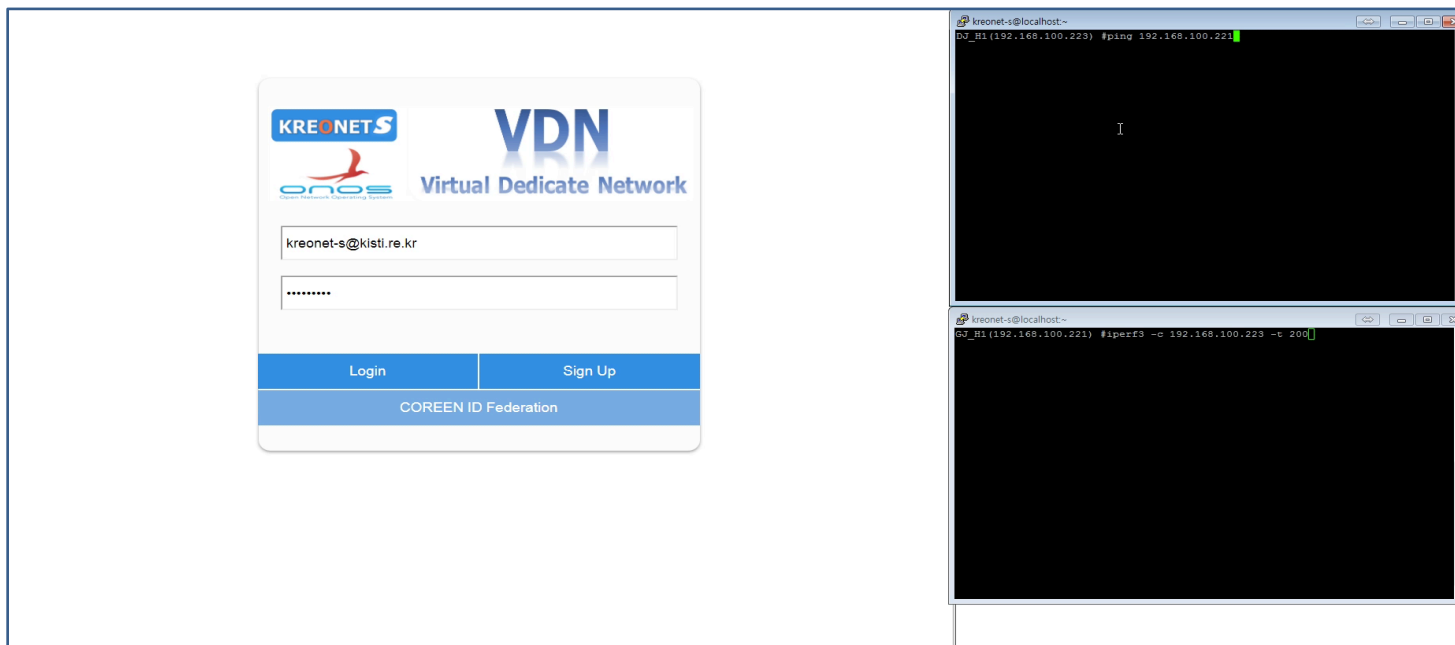


# Virtually Dedicated Networking (1)

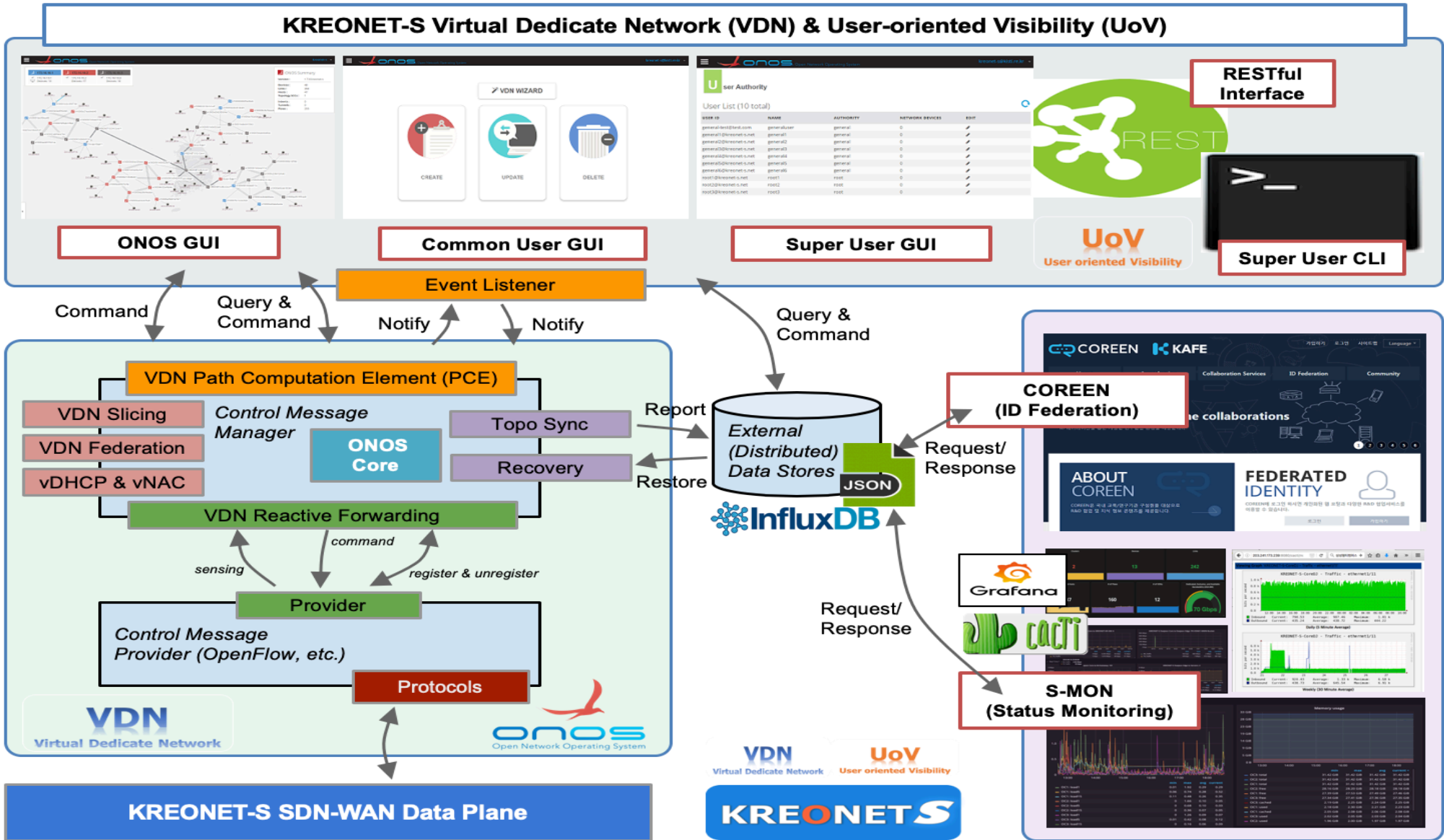
- VDN Designs & Features

<http://www.kreonet-s.net>

- **User-based Dynamic On-demand Virtual Network Management**
- **Logically Isolated and Dedicated Networking** w/ High Performance (~100Gbps) and Network Security Provisioning
- **ONOS-based Event Detection (e.g. Link up/down) and Recovery**
- **GUI-based Intuitive Virtual Network Creation, Update and Deletion**
- **Additional App Development: vNAC, vFed, vSlicing, vDHCP, and VDNO**



# KREONET-S/VDN Architecture



# Virtual Network Access Control

- VDN/SDN-IP with vNAC
  - The 4-tuple network access control is provided for each VDN so that users can easily configure their own (simple) security policy on the VDNs
    - **Allow By Default:** General flow “allow”, User defined flow “deny”
    - **Deny By Default:** General flow “deny”, User defined flow “allow”

**create**

Name: PR-VDN01-WWW-Bucket ☒ Is the proper name.

Bandwidth: 1 Gbps ☐ Auto Scale ☐ Proactive

SDN-IP Gateway: KREONET-KR-Gateway (210.110.196.1) Default Access: Allow ☒ Deny ☐

DHCP Server: Default DHCP

User List: All Users Selected User(s)

Location: Network Devices Hosts/GW

Daegu: KREONET-S-DJ-Core\* KREONET-KR-Gateway

Daegu: KREONET-S-DJ-Core\* vDHCP1-Gateway

Daegu: Daegu-Edge\* KREONET-S-WWW

Daegu: Daegu-Edge\* KREONET-S-BB-Bucket

Daegu: Daegu-Edge\* 210.110.196.23

**create**

Name: PR-VDN01-WWW-Bucket ☒ Is the proper name.

Bandwidth: 1 Gbps ☐ Auto Scale ☐ Proactive

SDN-IP Gateway: KREONET-KR-Gateway (210.110.196.1) Default Access: Allow ☒ Deny ☐

GUI for VDN Creation  
(including SDN-IP Gateway w/ vNAC)

**Create Rule**

VDN: PR-VDN01-WWW-Bucket (c9370a06-2ddf-4ebe-bc20-e9a9cc9912aa)

Gateway: KREONET-KR-Gateway (210.110.196.1)

Protocol: TCP

Action: Deny

Source IP (outbound): 210.110.196.1/24

Destination IP (outbound): input dst IP

Destination Port: 80

Do you want to create rule?

**GUI for List of vNAC Rule**

Firewall flow rules (2 total)

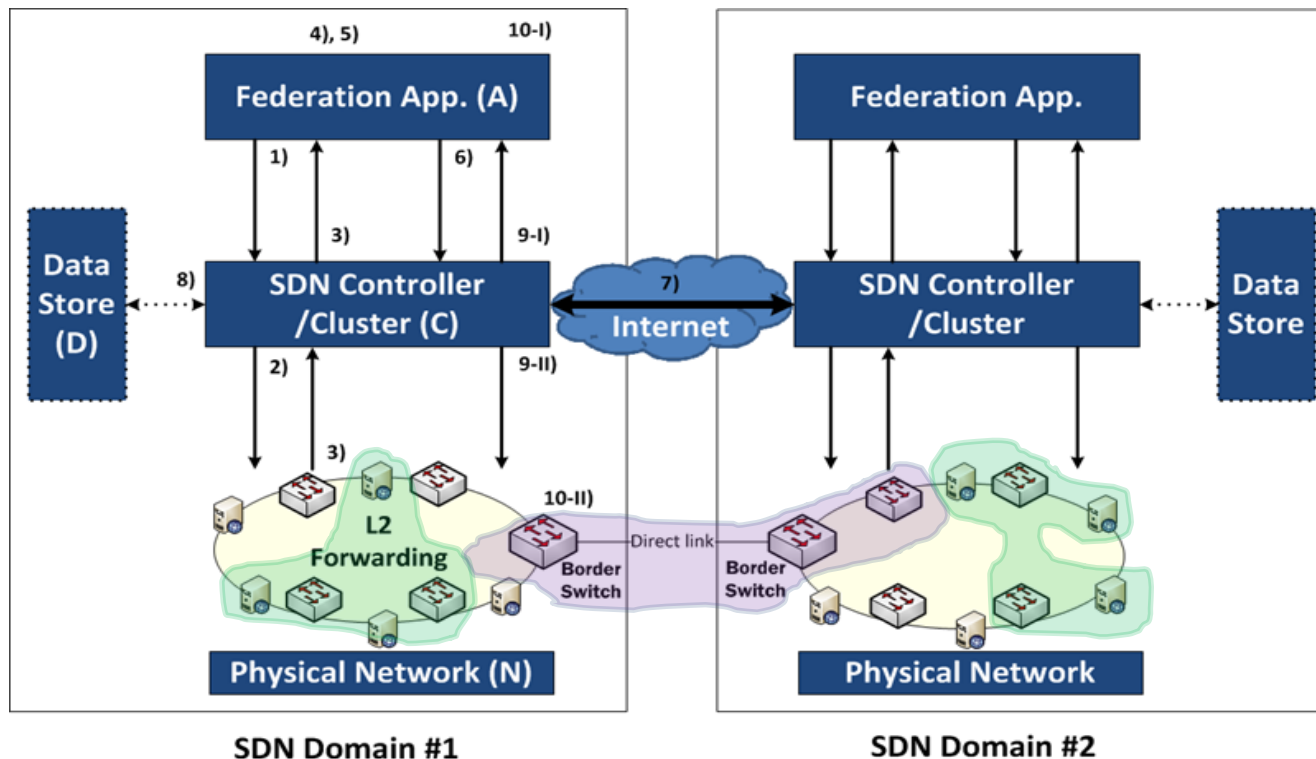
VDN	GATEWAY	GROUP ID	PROTOCOL	ACTION	RULE ID	SOURCE	DESTINATION	DESTINATION PORT
PR-VDN01-WWW-Bucket	KREONET-KR-Gateway	0x1048597	TCP	DENY	0x58	08:00:27:10:55:88	64:A0:E7:D3:36:43	80
					0x59	64:A0:E7:D3:36:43	08:00:27:10:55:88	
					0x5a	08:00:27:F9:6A:87	64:A0:E7:D3:36:43	
					0x5b	64:A0:E7:D3:36:43	08:00:27:F9:6A:87	
					0x5c	08:00:27:AA:96:4C	64:A0:E7:D3:36:43	
					0x5d	64:A0:E7:D3:36:43	08:00:27:AA:96:4C	
					0x5e	64:A0:E7:D3:36:47	64:A0:E7:D3:36:43	
					0x5f	64:A0:E7:D3:36:43	64:A0:E7:D3:36:47	
PR-VDN01-WWW-Bucket	KREONET-KR-Gateway	0x1048596	TCP	DENY	0x57	210.110.196.21/32	64:A0:E7:D3:36:43	80
						210.110.196.21/32		

GUI for vNAC Rule Creation

GUI for List of vNAC Rule

# Virtual Network Federation

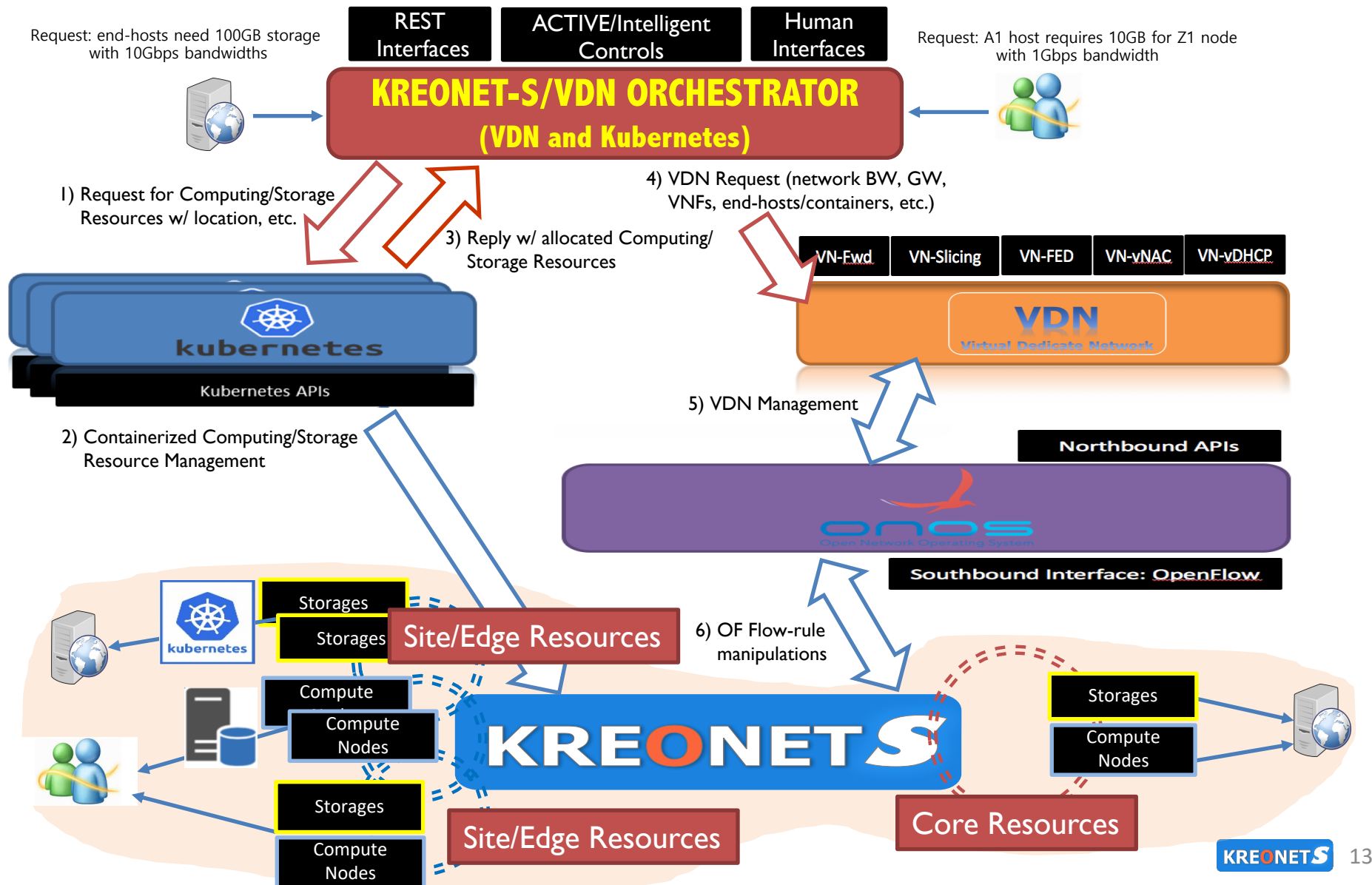
- Inter-Communications for individual SDN/VDN Domains
  - **Inter-VDN connections** with guaranteed network performance **between different SDN control domains** over SDN-WAN for **inter-SDN connectivity & resource federation**, e.g., between KREONET-S, CST-Cloud, DCs, Campuses, etc.



## Basic Procedure

- [Preliminary] VDN Generation
- [Step 1] Exchange Information (VDN, Controller IP, BS ID/Port)
- [Step 2] Configure VDN Federation Information
- [Step 3] Create Peer (Bogus) Host(s) Connected to the BS Port
- [Step 4] Update VDN (Including Peer Host(s))
- [Data Transmission] Use Own Fwd Method Independently

# VDN and k8s Orchestration (1)



# VDN and k8s Orchestration (2)

- Auto-Selection and Allocation of Service/Container Resources based on Locations and Loads ( $c_{selected}$ )

$$c_{selected} = \text{Max} \{ \text{for all } c_i \in C \mid \omega_{location} \cdot c_{location} + \omega_{resource} \cdot c_{resource} \}$$

where 1)  $\omega_{location}$  and  $\omega_{resource} \geq 0$ , 2)  $\omega_{location} + \omega_{resource} = 1$ .

- Metric 1 ( $c_{location}$ ): location proximity to each end-host w/ weights

$$c_{location} = \alpha \cdot l_{C_i, L_j} + \beta \cdot cv_{C_i}$$

where 1)  $c_i \in C, l_i \in L, C \subseteq L$ , 2)  $\alpha$  and  $\beta \geq 0$ , 3)  $\alpha + \beta = 1$ .

- Metric 2 ( $c_{resource}$ ): resource utilization (CPU/memory/storage)

$$c_{resource} = a_1 \cdot r_{nor}(c, C_i) + a_2 \cdot r_{nor}(m, C_i) + a_3 \cdot r_{nor}(s, C_i)$$

where 1)  $r(c, C_i) \geq d(c), r(m, C_i) \geq d(m), r(s, C_i) \geq d(s)$ ,

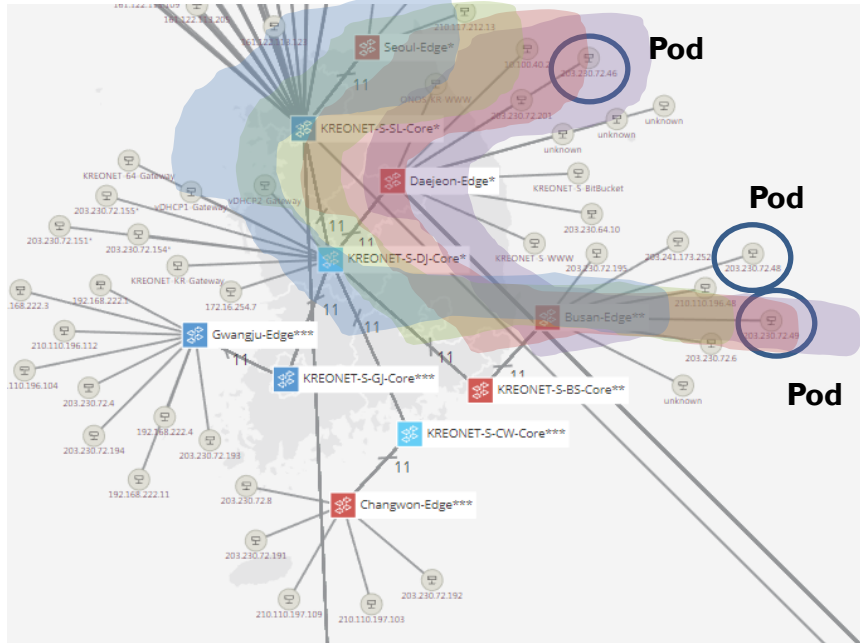
2)  $r_{nor}(c, C_i), r_{nor}(m, C_i), r_{nor}(s, C_i)$ : normalized factor ( $0 \leq r_{nor} \leq 1$ ),

3)  $a_n \geq 0, a_1 + a_2 + a_3 = 1$ .

Notation	Description
$L$	Set of locations of distributed end hosts
$C$	Set of locations deployed k8s infrastructure
$l_{i,j}$	Normalized link capacity between location i and j, $0 \leq l_{i,j} \leq 1$
$cv_i$	Normalized centrality value of location i, $0 \leq cv_i \leq 1$
$d(c)$	Initial service CPU resources demand
$d(m)$	Initial service memory resources demand
$d(s)$	Initial service storage resources demand
$r(c, C_i)$	Available CPU resources in cloud $C_i$
$r(m, C_i)$	Available memory resources in cloud $C_i$
$r(s, C_i)$	Available storage resources in cloud $C_i$

# VDN-Container Network Interface

- **VDN-CNI:Host-device Performance**
  - I/I0G Multiple VDNs provisioned for k8s DTNs

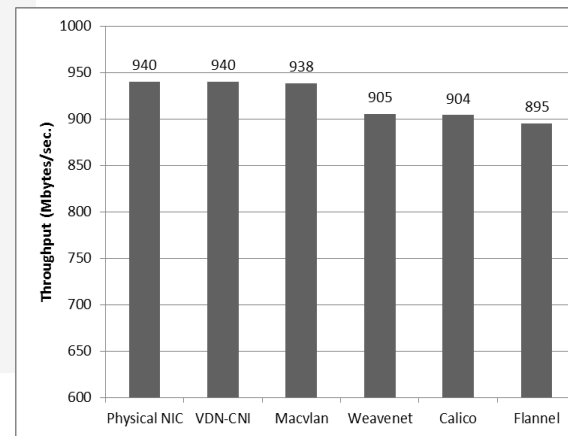


[ONOS Topology GUI]

```
root@ubuntu2:/# iperf3 -s
Server listening on 5201

Accepted connection from 203.230.72.48, port 47518
[ 5] local 203.230.72.46 port 5201 connected to 203.230.72.48
[ ID] Interval      Transfer    Bandwidth
[ 5] 0.00-1.00 sec  106 MBytes  890 Mbits/sec
[ 5] 1.00-2.00 sec  112 MBytes  942 Mbits/sec
[ 5] 2.00-3.00 sec  112 MBytes  942 Mbits/sec
[ 5] 3.00-4.00 sec  112 MBytes  942 Mbits/sec
[ 5] 4.00-5.00 sec  112 MBytes  941 Mbits/sec
[ 5] 5.00-6.00 sec  112 MBytes  942 Mbits/sec
[ 5] 6.00-7.00 sec  112 MBytes  942 Mbits/sec
[ 5] 7.00-8.00 sec  112 MBytes  942 Mbits/sec
[ 5] 8.00-9.00 sec  112 MBytes  942 Mbits/sec
[ 5] 9.00-10.00 sec 112 MBytes  942 Mbits/sec
[ 5] 10.00-10.04 sec 5.01 MBytes  941 Mbits/sec
[ ID] Interval      Transfer    Bandwidth
[ 5] 0.00-10.04 sec 1.10 GBytes  938 Mbits/sec
[ 5] 0.00-10.04 sec 1.09 GBytes  936 Mbits/sec
```

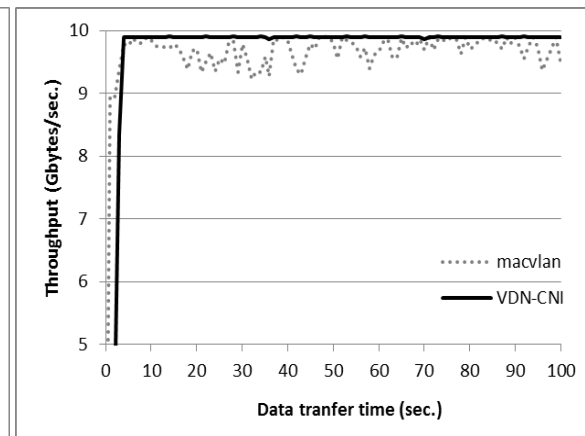
[1G Test (iperf3): 940M]



[Throughput of DTN pairs in 1G VDN]

```
root@ubuntu-host:/# iperf3 -c 203.230.72.54 -p 5201 -t 5
Connecting to host 203.230.72.54, port 5201
[ 4] local 203.230.72.63 port 38382 connected to 203.230.72.54 port 5201
[ ID] Interval      Transfer    Bandwidth    Retr  Cwnd
[ 4] 0.00-1.00 sec  579 MBytes  4.86 Gbits/sec  4    4.29 MBytes
[ 6] 0.00-1.00 sec  576 MBytes  4.83 Gbits/sec  1    2.91 MBytes
[SUM] 0.00-1.00 sec  1.13 GBytes  9.69 Gbits/sec  5
[ ID] Interval      Transfer    Bandwidth    Retr  Cwnd
[ 4] 1.00-2.00 sec  590 MBytes  4.95 Gbits/sec  0    4.29 MBytes
[ 6] 1.00-2.00 sec  590 MBytes  4.95 Gbits/sec  1    2.91 MBytes
[SUM] 1.00-2.00 sec  1.15 GBytes  9.90 Gbits/sec  1
[ ID] Interval      Transfer    Bandwidth    Retr  Cwnd
[ 4] 2.00-3.00 sec  590 MBytes  4.95 Gbits/sec  0    4.29 MBytes
[ 6] 2.00-3.00 sec  590 MBytes  4.95 Gbits/sec  0    2.91 MBytes
[SUM] 2.00-3.00 sec  1.15 GBytes  9.90 Gbits/sec  0
[ ID] Interval      Transfer    Bandwidth    Retr  Cwnd
[ 4] 3.00-4.00 sec  590 MBytes  4.95 Gbits/sec  0    4.29 MBytes
[ 6] 3.00-4.00 sec  590 MBytes  4.95 Gbits/sec  0    2.94 MBytes
[SUM] 3.00-4.00 sec  1.15 GBytes  9.90 Gbits/sec  0
[ ID] Interval      Transfer    Bandwidth    Retr  Cwnd
[ 4] 4.00-5.00 sec  590 MBytes  4.95 Gbits/sec  0    4.29 MBytes
[ 6] 4.00-5.00 sec  590 MBytes  4.95 Gbits/sec  0    2.94 MBytes
[SUM] 4.00-5.00 sec  1.15 GBytes  9.90 Gbits/sec  0
[ ID] Interval      Transfer    Bandwidth    Retr  Cwnd
[ 4] 5.00-6.00 sec  590 MBytes  4.93 Gbits/sec  4
[ 6] 5.00-6.00 sec  2.87 GBytes  4.93 Gbits/sec  2
[SUM] 5.00-6.00 sec  5.74 GBytes  9.86 Gbits/sec  6
[ ID] Interval      Transfer    Bandwidth    Retr  Cwnd
[ 4] 6.00-7.00 sec  590 MBytes  4.93 Gbits/sec  4
[ 6] 6.00-7.00 sec  2.87 GBytes  4.93 Gbits/sec  2
[SUM] 6.00-7.00 sec  5.74 GBytes  9.85 Gbits/sec  6
```

[10G Test (iperf3): 9.86G]




[Throughput of DTN pairs in 10G VDN]

# ONF Connect 2018 Demos

- **Demo #1:** Location and Load aware Virtually Dedicated Container Networking over KREONET-S with a New VDN-CNI Implemented
- **Demo #2:** VDN International Federation over KREONET-S (KR) and CST-Cloud (CN)

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#31 Location and Load aware Virtually Dedicated Container Networking over KREONET-S







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resources which are deployed in eight distributed centers in Korea (3), USA (2), and China (1). In the orchestrator intelligently decides the nearest server the users after receiving their service requests, the load (e.g., CPU, memory, and storage usage) status information acquired from container management information. Here, container manager work management in association with VDN-CNI which connect the provisioned pods to ONOS/VDN in allocating either shared or dedicated networking. Eventually orchestrator communicates with virtual provide the requested complete set of service resources through manipulating virtually dedicated network being composed of (distributed) service pods, use required network gateways, and proper virtual network such as VDHCP and virtual network access control.

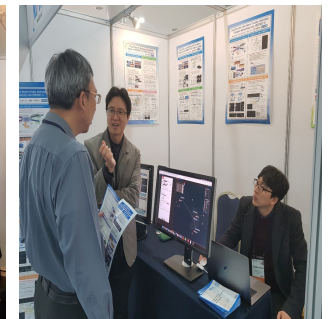
In this talk, the implemented orchestration system and functions will be lively demonstrated using a testbed over KREONET-S, with the overall architecture described in detail.

You are an **author** of this submission.  
[Edit submission](#)



# APAN47 Demos (2019)

- **Demo #1:** Location and Load aware Virtually Dedicated Container Networking over KREONET-S with a New VDN-CNI Implemented
- **Demo #2:** VDN Federation over KREONET-S (KR) and CST-Cloud (CN)



# Advanced NREN Collaborations

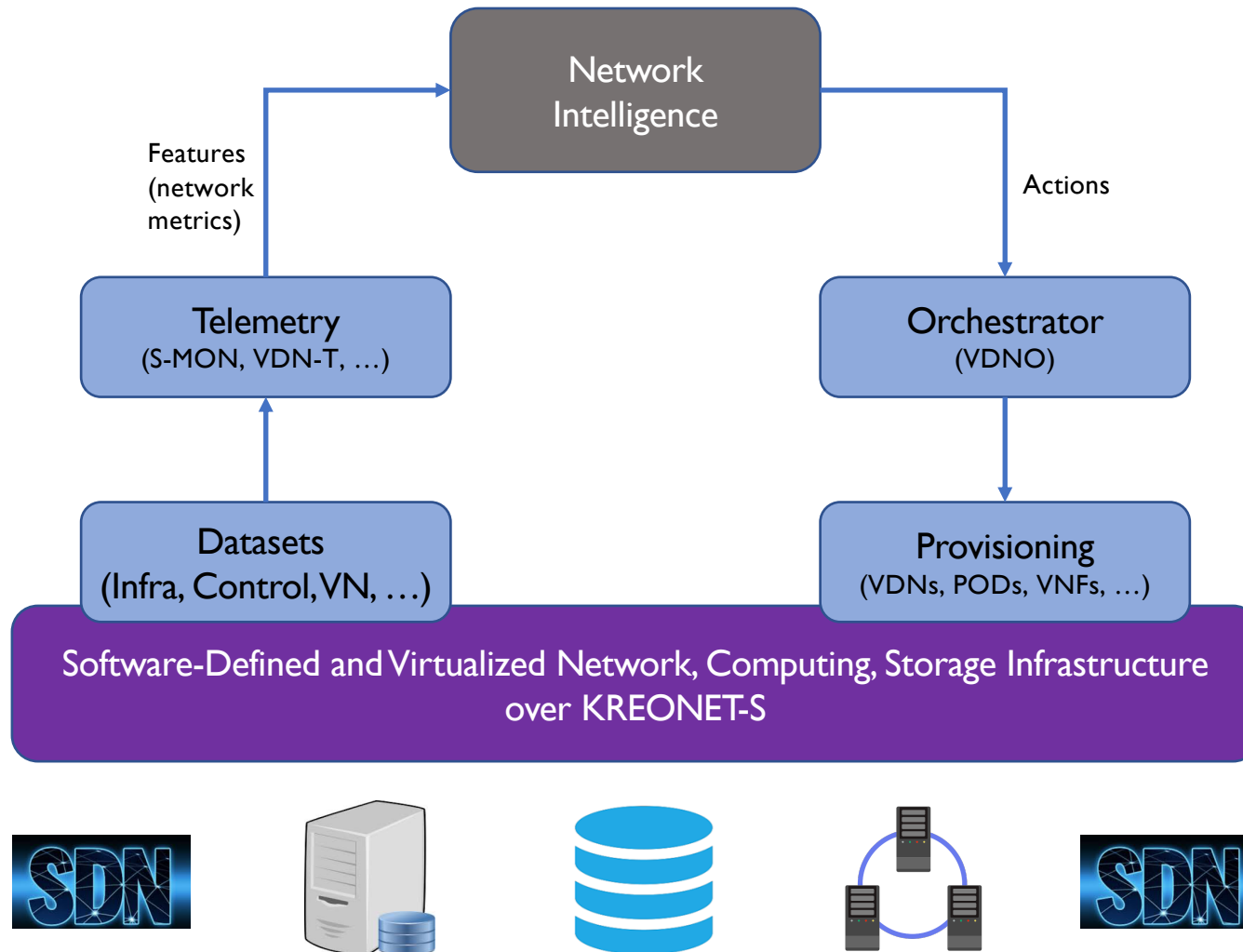
- Advanced Research Networks in USA, Europe, China, etc.
  - Internet2 (US): Network Automation/Intelligence (Ana Hunsinger, Vice President)
  - ESNET (US): SDN-oriented WAN and Orchestration (Inder Monga, E. Director)
  - SURFNet (NL): Network Automation (Alexander Van Den Hill, Manager)
  - NORDUnet (N. Europe): Network Intelligence/SDMZ (Erik-Jan Bos, Director)
  - CSTNET (CN): Cloud Native and Virtual Networking (Yongmao Ren, D. Director)



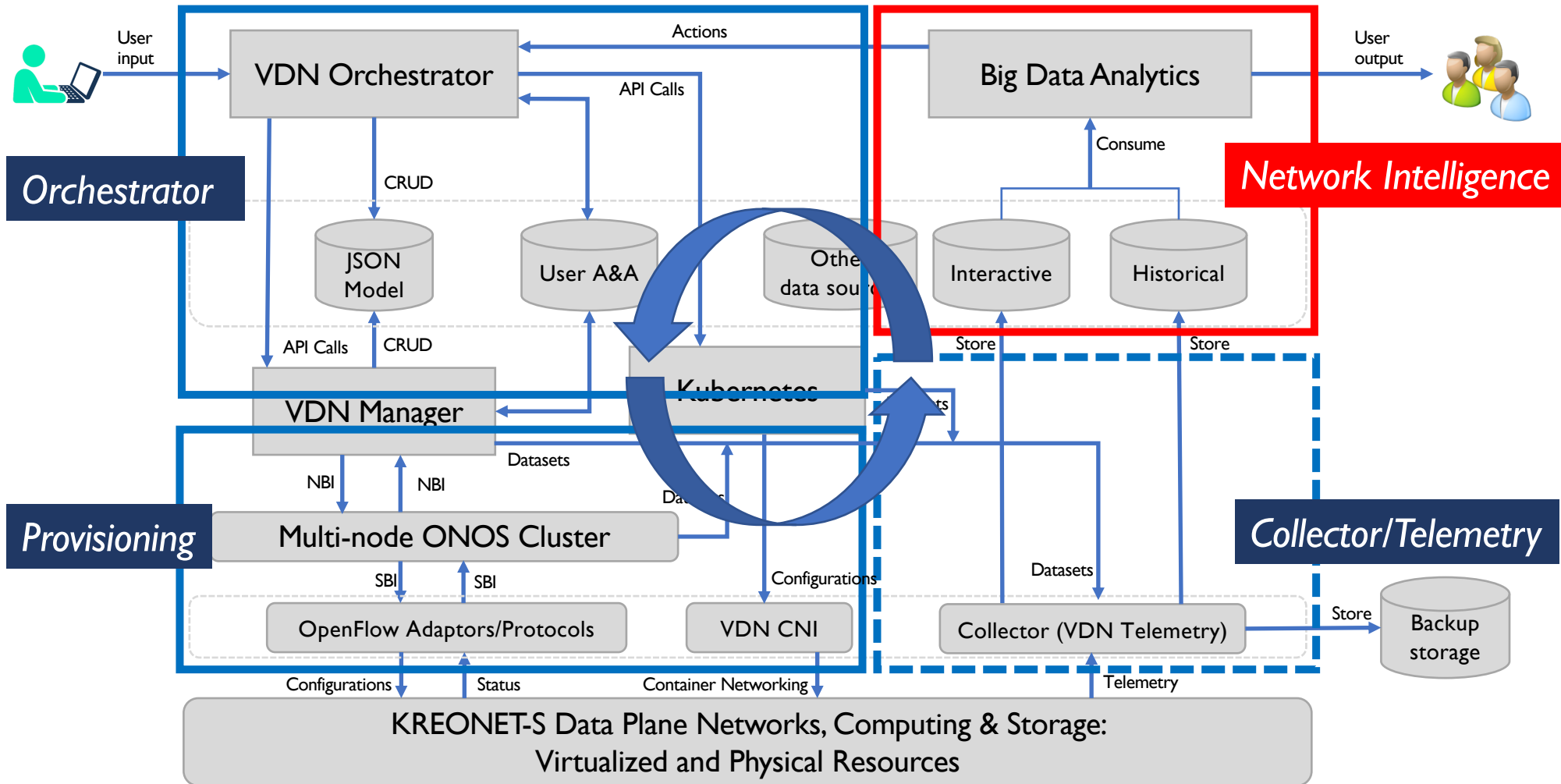
# Automated Virtual Networking



# NI Control Loop on KREONET-S (1)

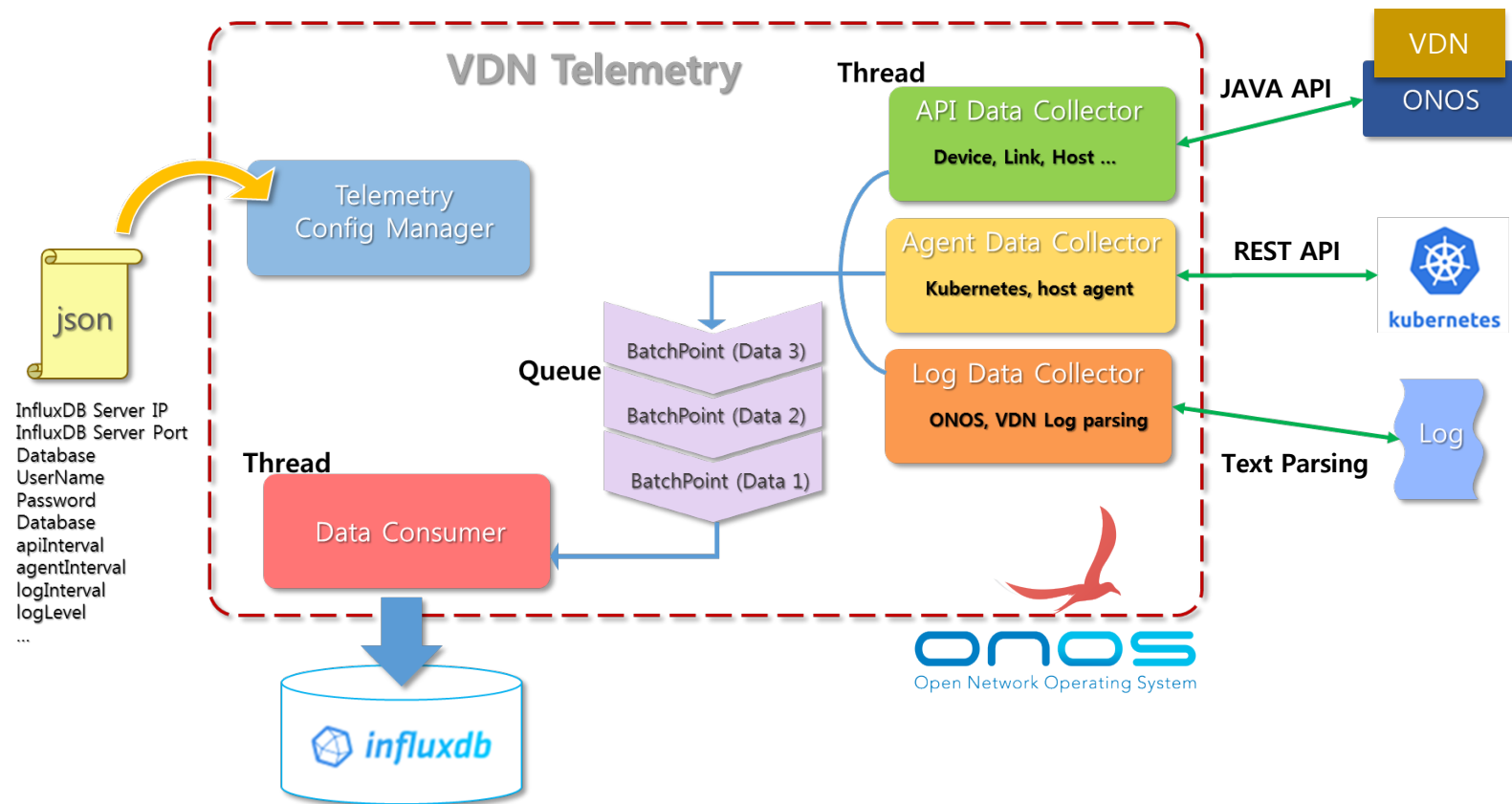


# NI Control Loop on KREONET-S (2)



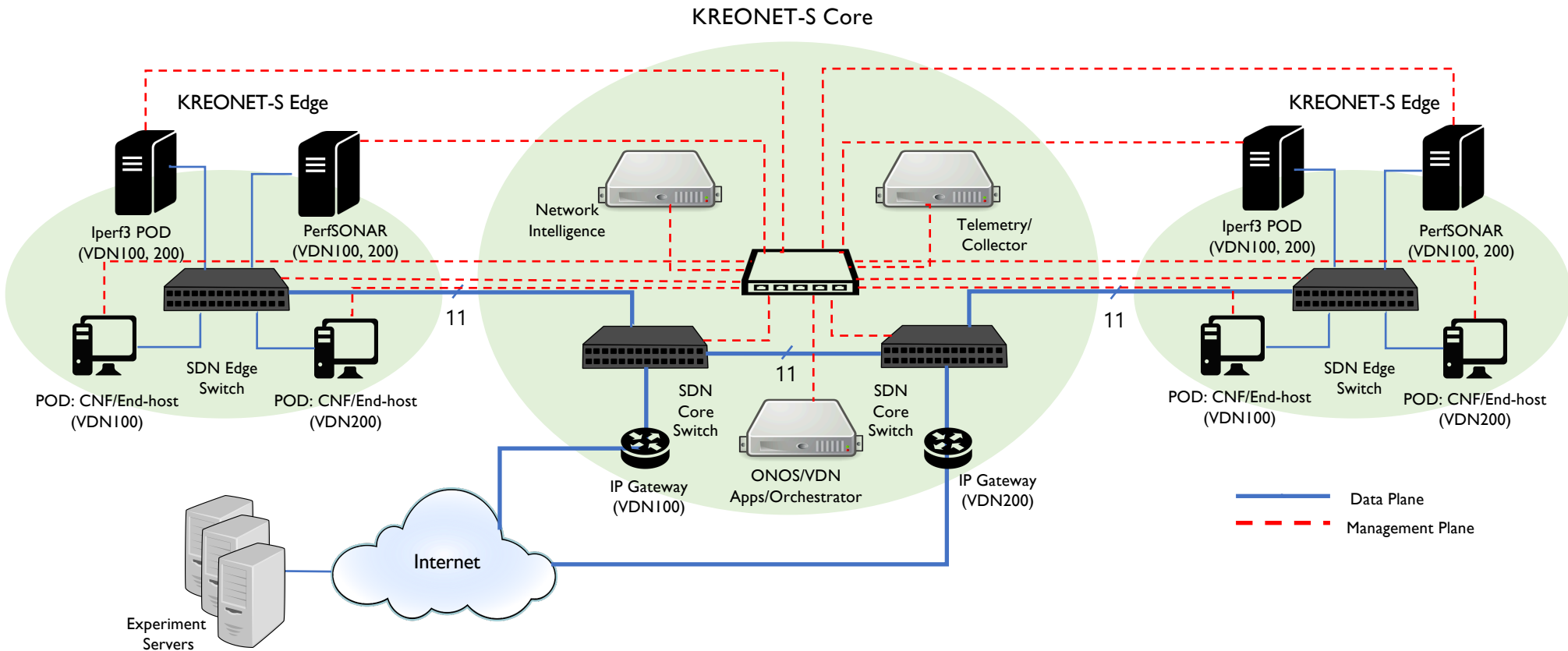
# VDN Telemetry

- Collecting Network Metrics from VN and CP Layers of KREONET-S



# NI Testbed using VDN/VDNO

- Intelligent Virtual Network Testbed Setup over KREONET-S (Draft)



# Conclusion

- **KREONET-S is Moving Forward**

- Software-Defined InterConnections and Automated E2E Orchestration
  - Auto-VDN, IoT Slicing, Virtual Edge SDMZ, Inter-VDN/VDNO Federation, etc.
- Network Intelligence for Autonomic Environment
  - VDN Telemetry + Big Data Analytics + VDN/VDNO Resource Provisioning

- **Further Work**

- New version of VDN (v2.0) and VDNO (v1.2) Releases
  - Enhanced Performance, Stability, UI with Network Intelligence and Automation
- Continuous KREONET-S SDN-WAN Expansion and Collaborations
  - ONOS/CORD WG (SDN/NFV Forum/KR), Future Infrastructure WG (Future Internet Forum/KR), Open Network Foundation, Global Research Platform, etc.
- Joint Research or Development with SDN/NFV Forum Members is Expected!

# Thank You!

Questions and/or Comments to

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For more Information

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