KREONET SOFTWARIZATION

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

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Open Networking Korea 2019 Fall

KREONETS

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 *****

KREONET-S: 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, TL1, 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

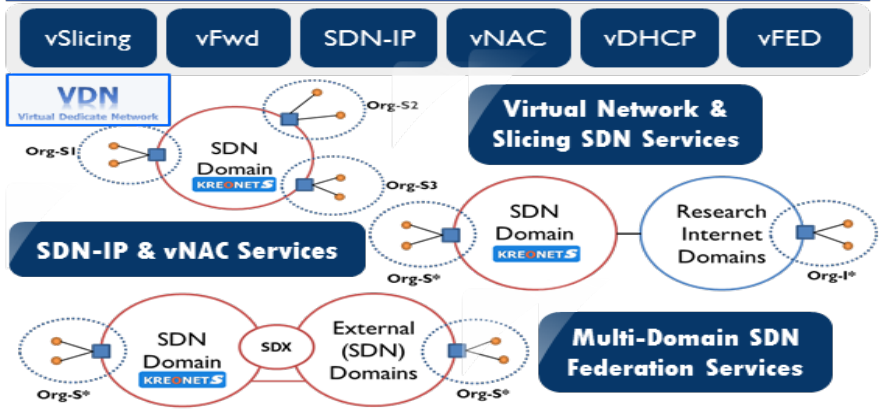
가상전용네트워킹(VDN) 기반 高성능/高대역/高보안성 제공

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

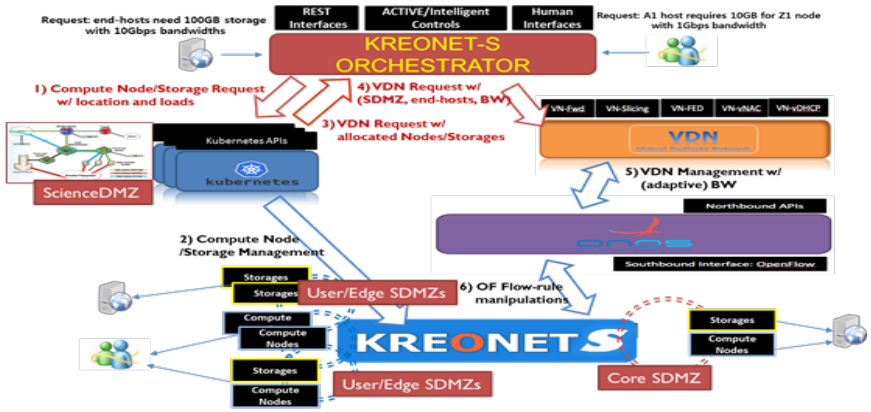
KREONET-S 서비스 지능화 /자동화 오케스트레이션(NI)

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

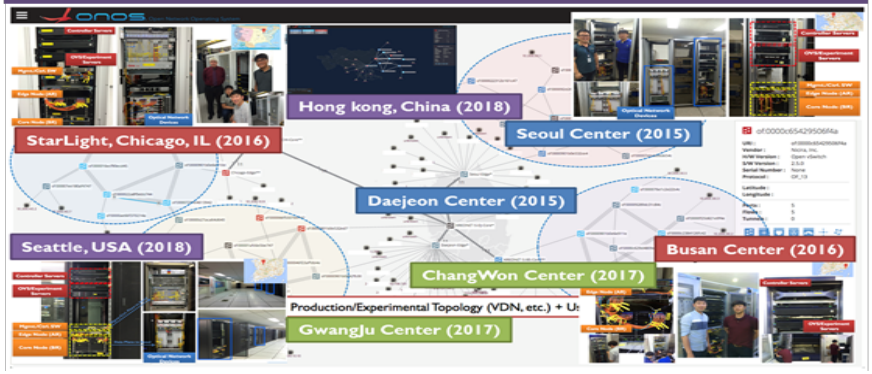
KREONET-S Virtualization & Service (VDN)



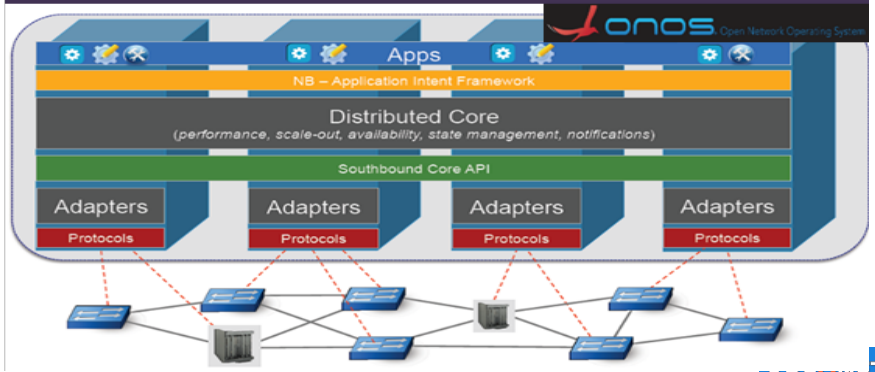
KREONET-S Orchestration & Intelligence (NI)



KREONET-S/SDN Data Plane

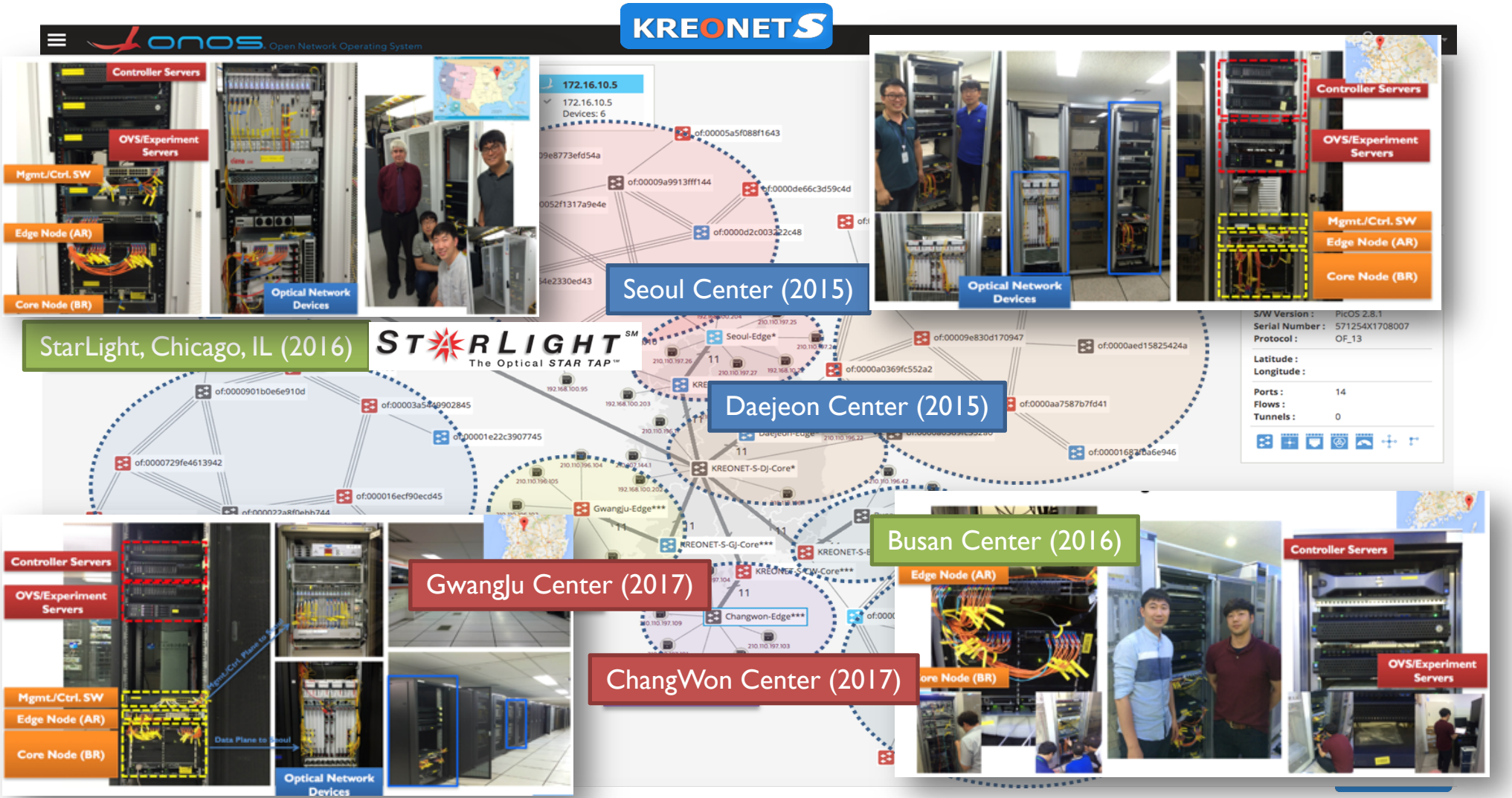


KREONET-S/SDN Control Plane



KREONET-S Infrastructure (1)

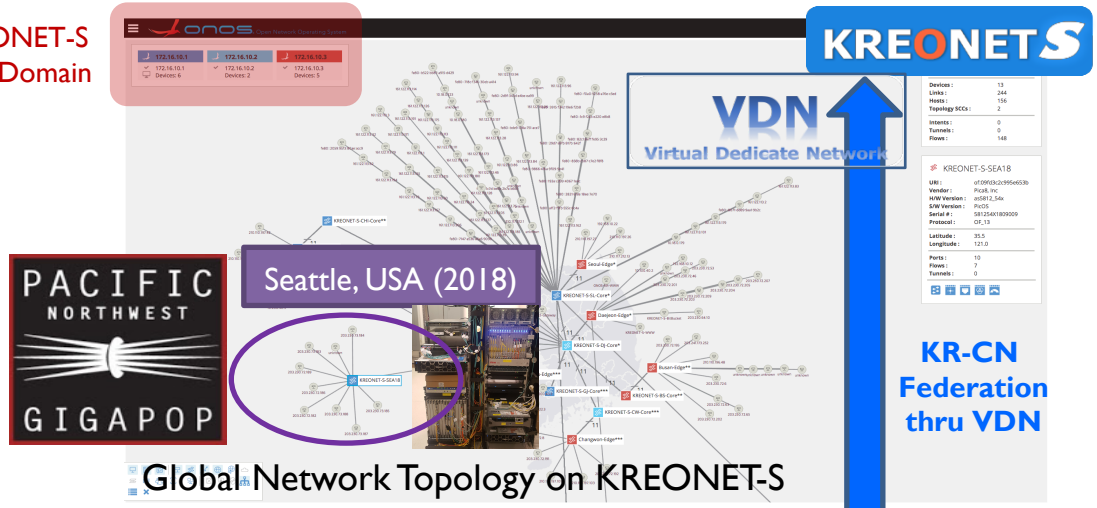
- 2015-2017 : Deployment in Six Locations in Korea and USA



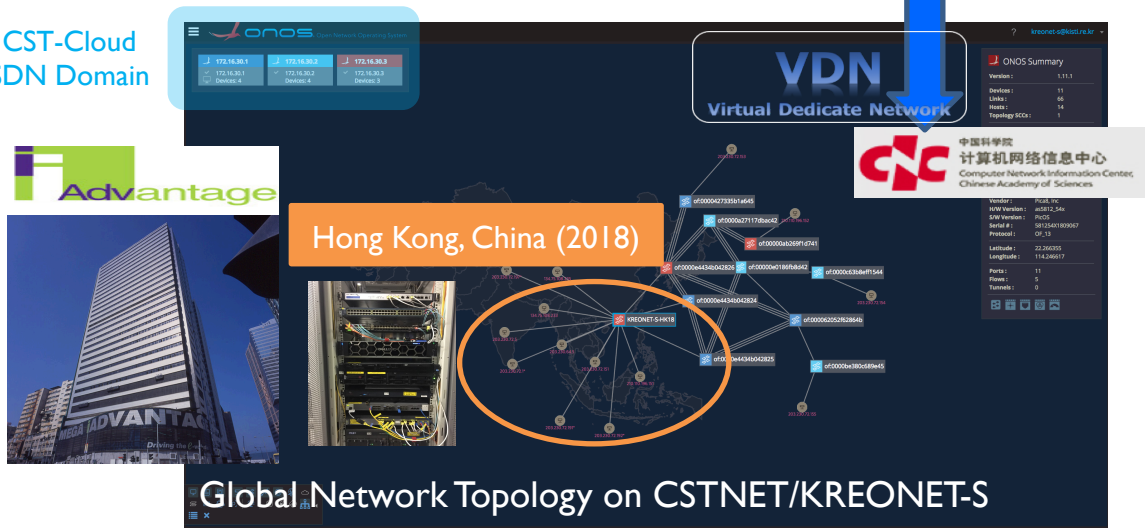
KREONET-S Infrastructure (2)

- 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



CST-Cloud SDN Domain

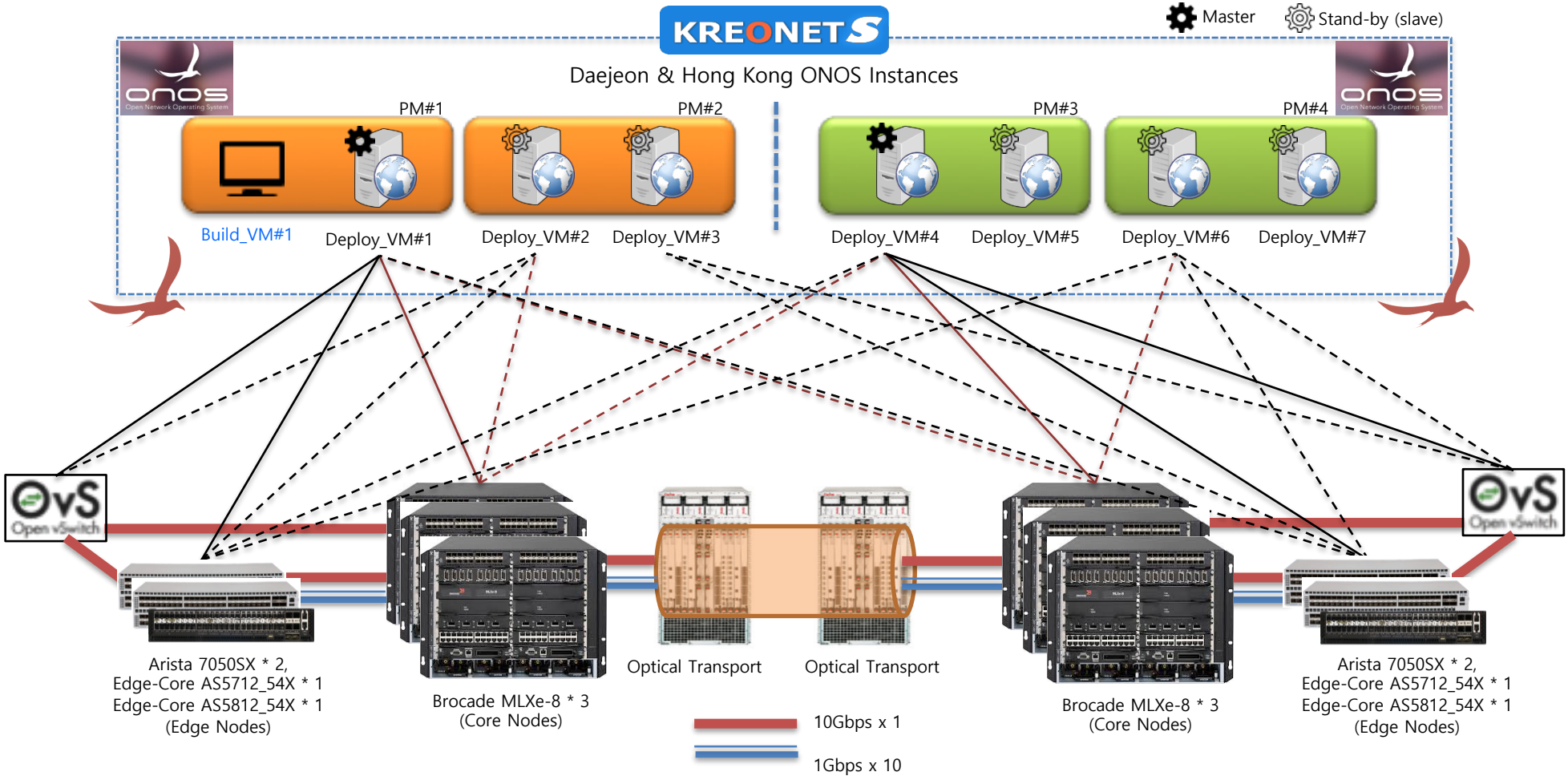



```
[root@localhost ~]# ping 203.230.72.191
PING 203.230.72.191 (203.230.72.191) 56(84) bytes of data.
64 bytes from 203.230.72.191: icmp_seq=1 ttl=64 time=47.4 ms
64 bytes from 203.230.72.191: icmp_seq=2 ttl=64 time=37.0 ms
64 bytes from 203.230.72.191: icmp_seq=3 ttl=64 time=334 ms
^C
--- 203.230.72.191 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=848 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, *v.1.11.1 Loon Release* (CN/HK Domain)

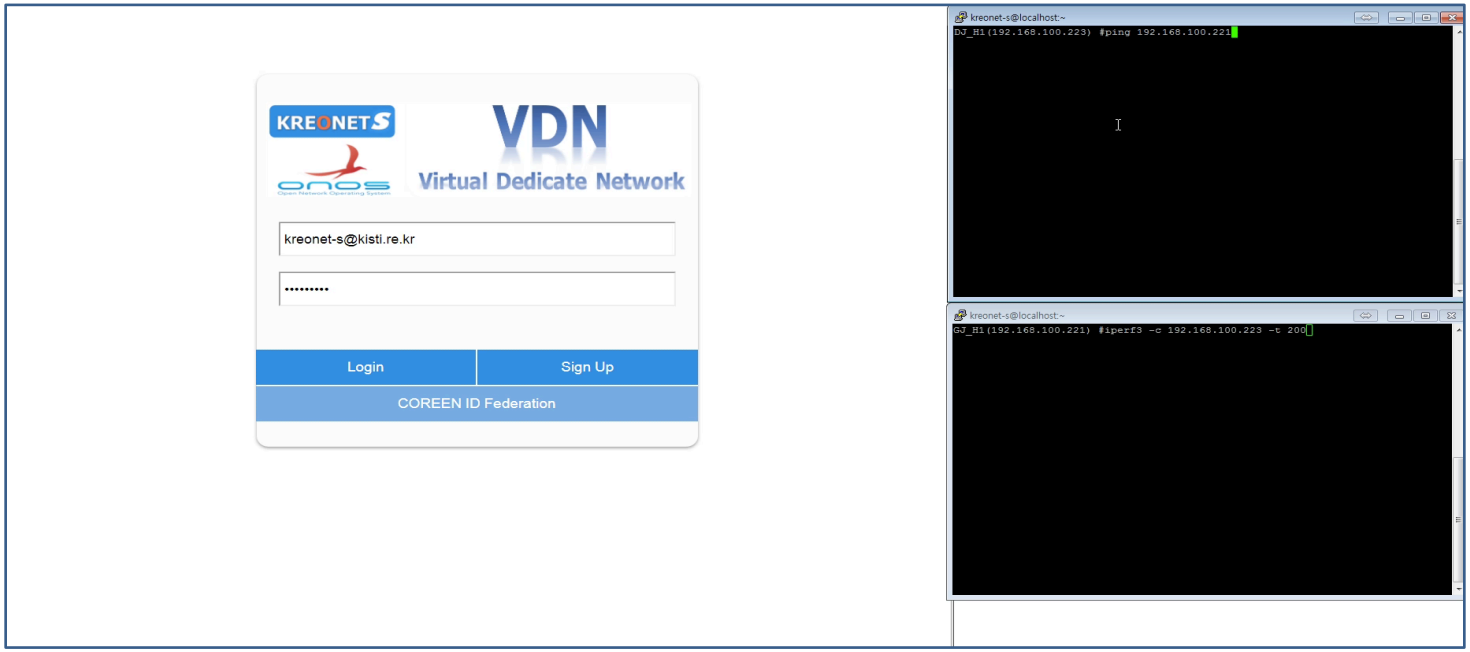


Virtually Dedicated Networking (1)

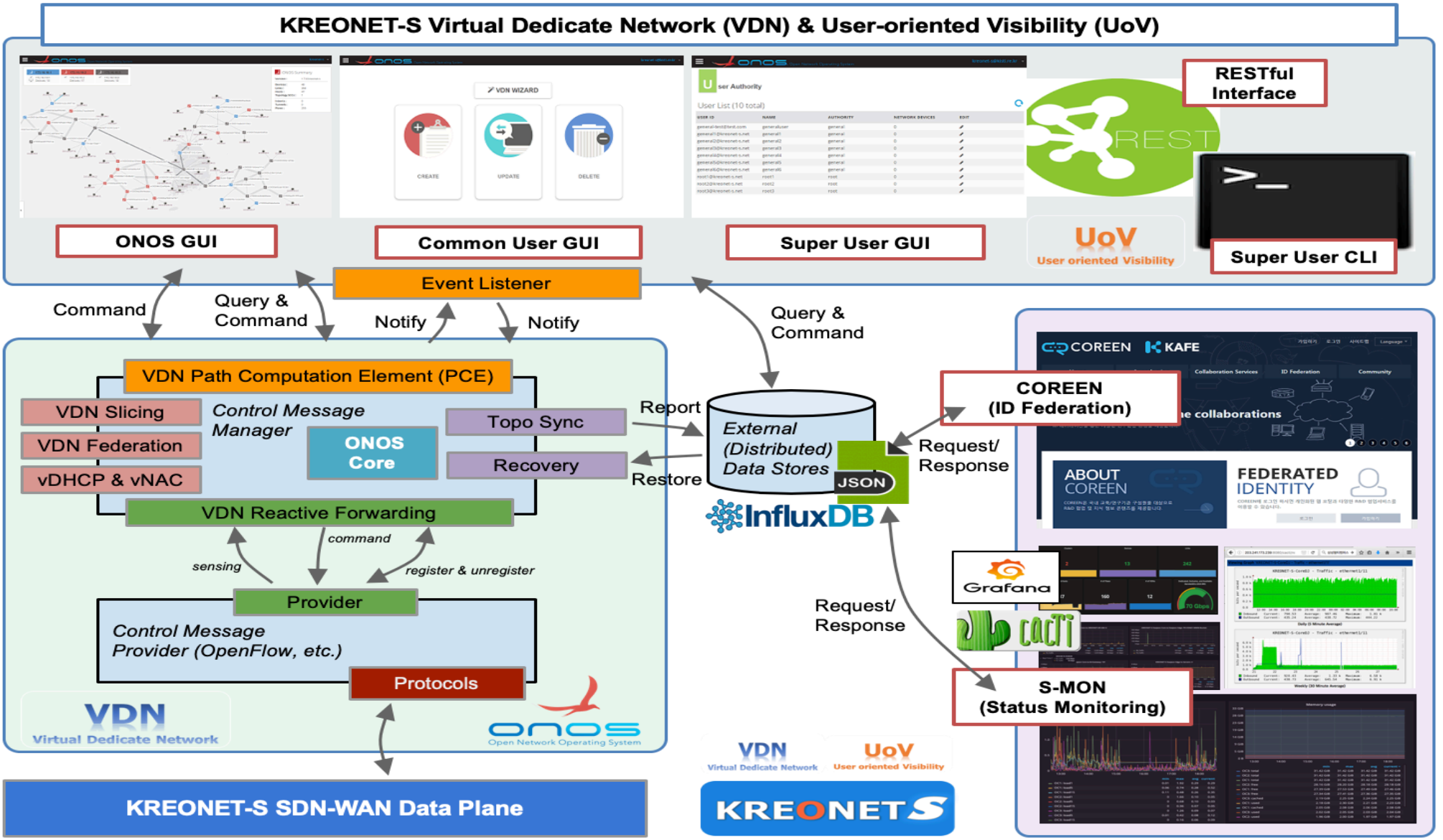
- VDN Designs & Features

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



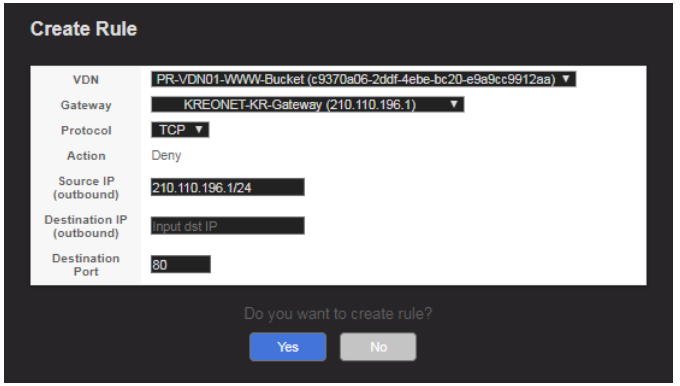
KREONET-S/VDN Architecture



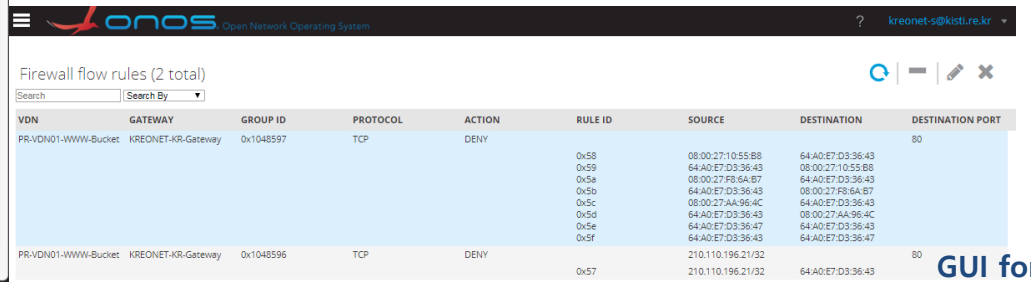
Virtual Network Access Control

- 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"

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



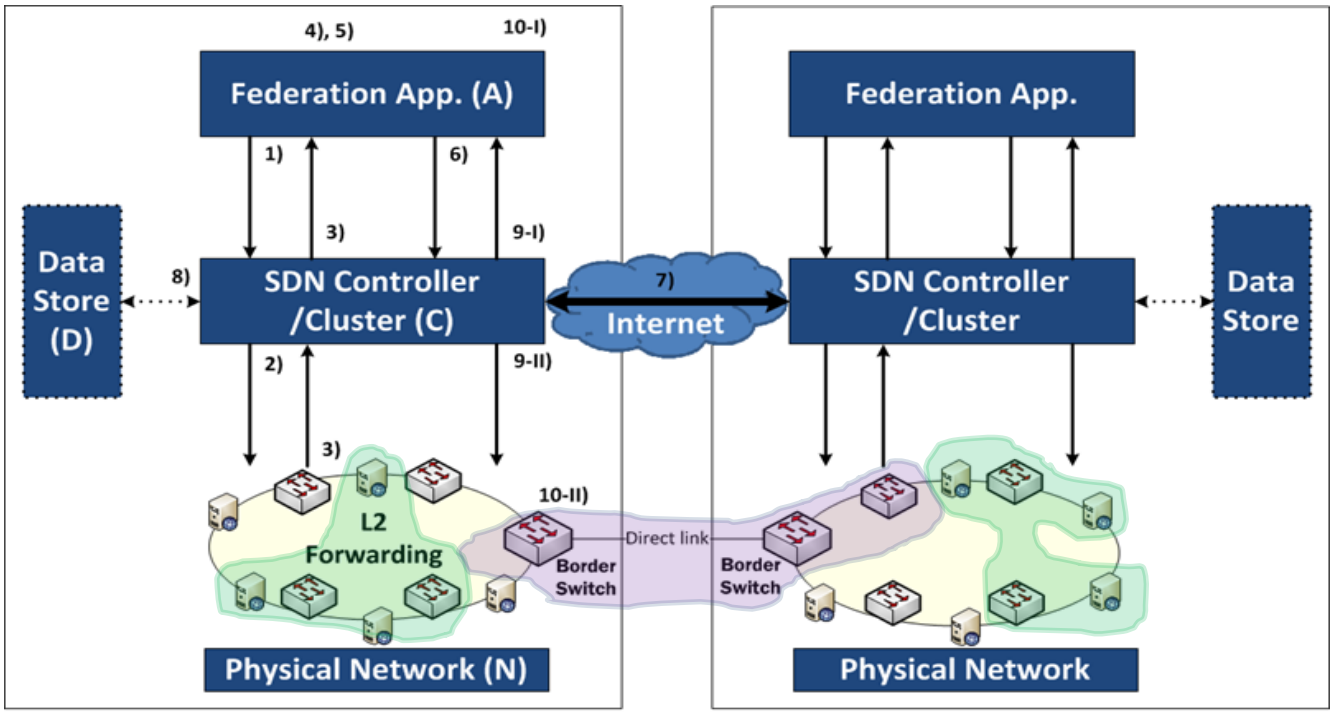
GUI for vNAC Rule Creation



GUI for List of vNAC Rule

Virtual Network Federation

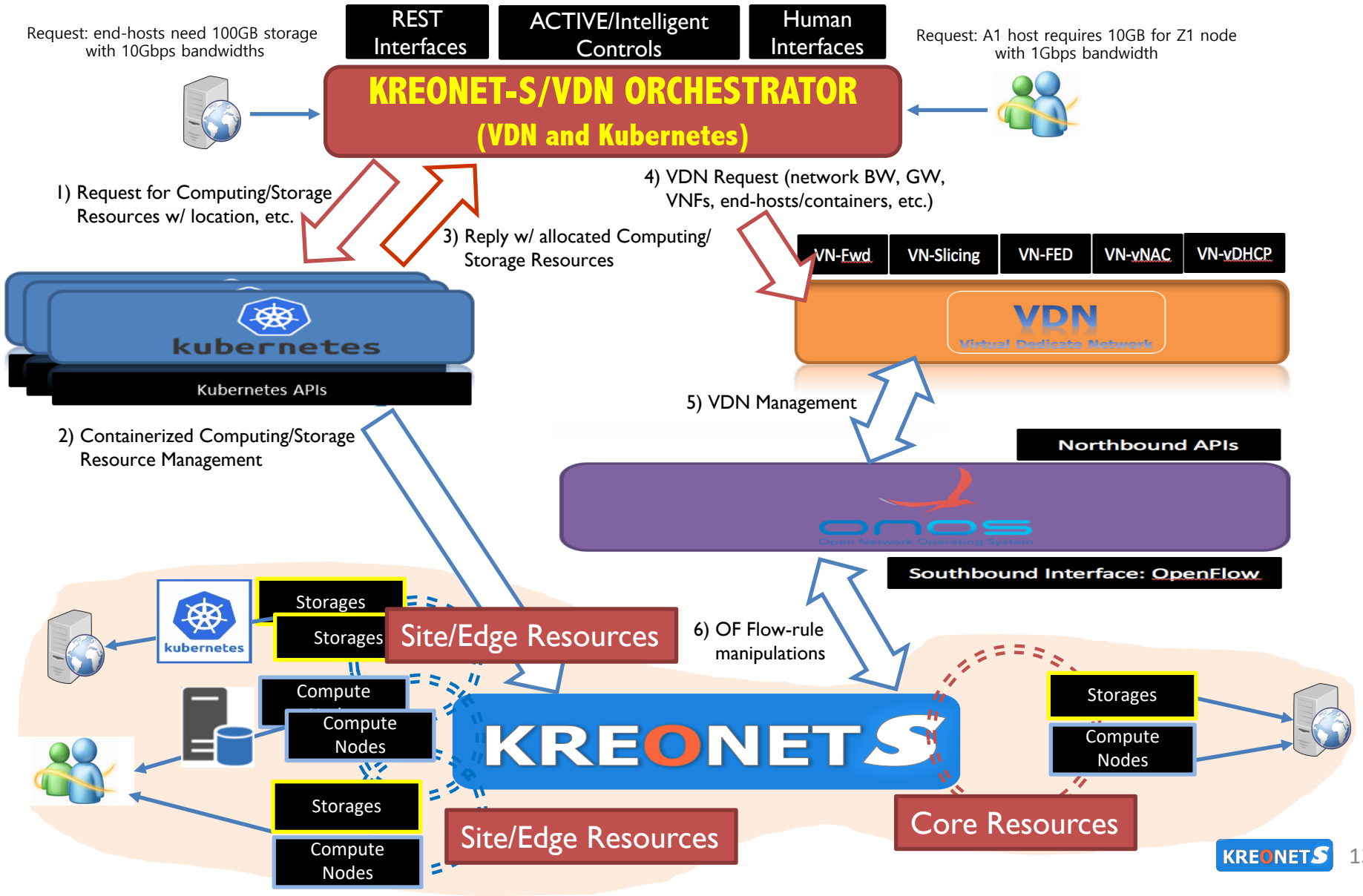
- Inter-Communications for individual SDN/VDN Domains
  - **Inter-VDN connections** with guaranteed network performance **between different SDN control domains** over SDN-WAN **for inter-SDN connectivity & resource federation,** e.g., between KREONET-S, CST-Cloud, DCs, Campuses, etc.



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 ($c_{selected}$)

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

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)

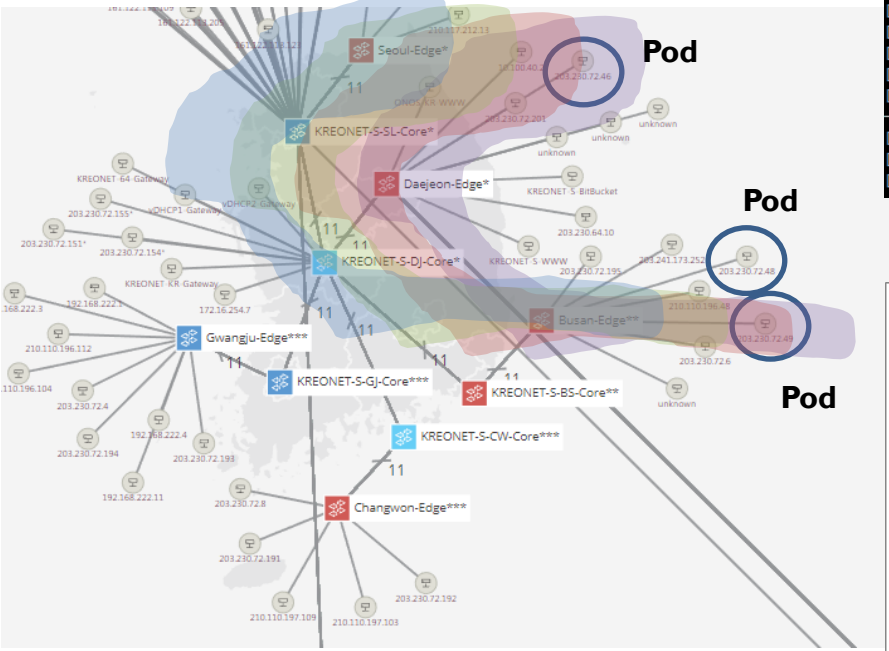
$$c_{resource} = a_1 \cdot r_{nor}(c, C_i) + a_2 \cdot r_{nor}(m, C_i) + a_3 \cdot r_{nor}(s, C_i)$$

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
$r(c, C_i)$	Availalble CPU resources in cloud C_i
$r(m, C_i)$	Availalble memory resources in cloud C_i
$r(s, C_i)$	Availalble storage resources in cloud C_i

VDN-Container Network Interface

- **VDN-CNI:Host-device Performance**
  - 1/10G Multiple VDNs provisioned for k8s DTNs



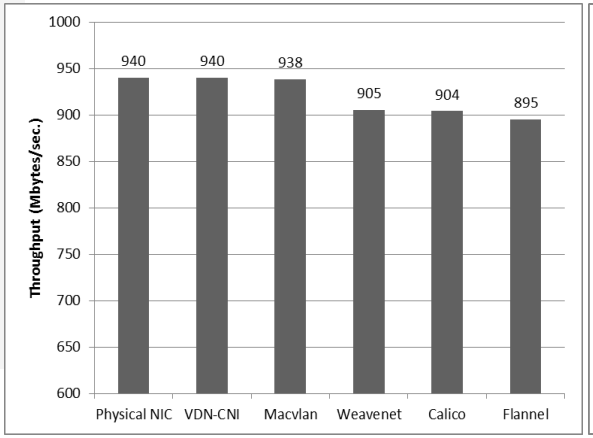
[ONOS Topology GUI]

```
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.
[ 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
```

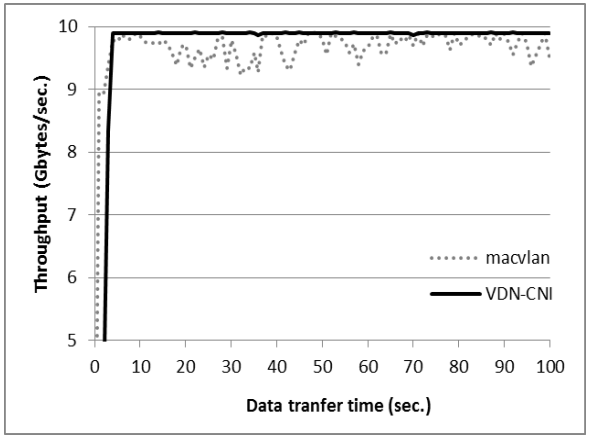
[1G Test (iperf3): 940M]

```
root@ubuntu-host:/# iperf3 -c 203.230.72.54 -P 2 -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
[  6] local 203.230.72.63 port 38384 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
- - - - - - - - - - - - - - - - - - - - - - - - -
[  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
- - - - - - - - - - - - - - - - - - - - - - - - -
[  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
- - - - - - - - - - - - - - - - - - - - - - - - -
[  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
- - - - - - - - - - - - - - - - - - - - - - - - -
[  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
[  4]   0.00-5.00   sec  2.87 GBytes  4.93 Gbits/sec    4             sender
[  4]   0.00-5.00   sec  2.87 GBytes  4.93 Gbits/sec                  receiver
[  6]   0.00-5.00   sec  2.87 GBytes  4.93 Gbits/sec    2             sender
[  6]   0.00-5.00   sec  2.87 GBytes  4.93 Gbits/sec                  receiver
[SUM]   0.00-5.00   sec  5.74 GBytes  9.86 Gbits/sec    6             sender
[SUM]   0.00-5.00   sec  5.74 GBytes  9.85 Gbits/sec                  receiver
```

[10G Test (iperf3): 9.86G]



[Throughput of DTN pairs in 1G VDN]

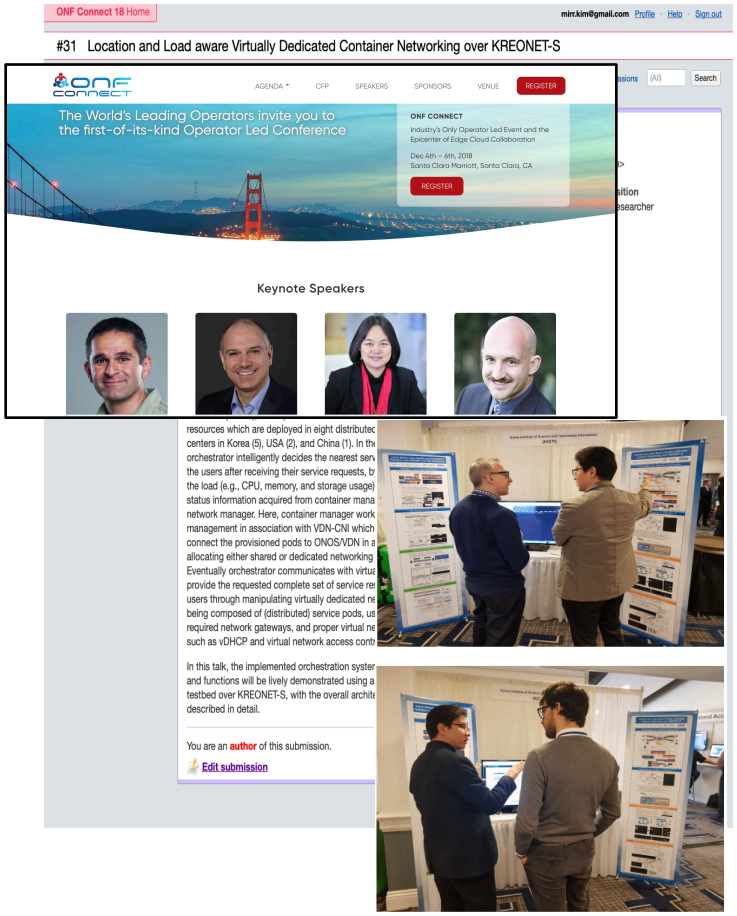


[Throughput of DTN pairs in 10G VDN]

KREONET

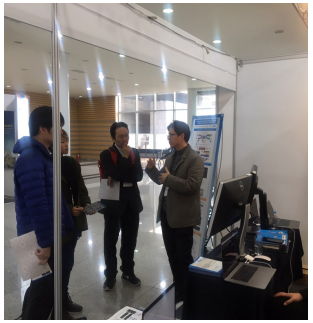
ONF Connect 2018 Demos

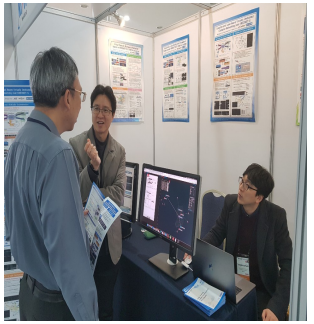
- Demo #1: Location and Load aware Virtually Dedicated Container Networking over KREONET-S with a New VDN-CNI Implemented
- Demo #2: VDN International Federation over KREONET-S (KR) and CST-Cloud (CN)



APAN47 Demos (2019)

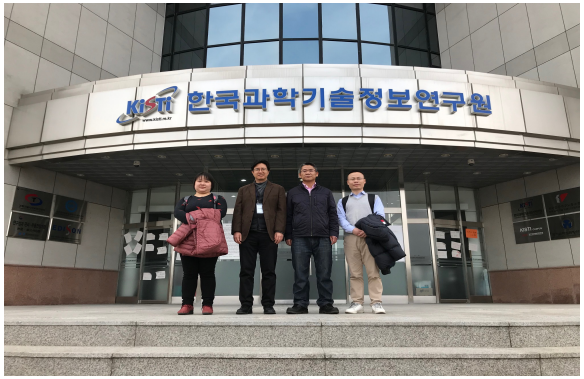
- Demo #1: Location and Load aware Virtually Dedicated Container Networking over KREONET-S with a New VDN-CNI Implemented
- Demo #2: VDN Federation over KREONET-S (KR) and CST-Cloud (CN)





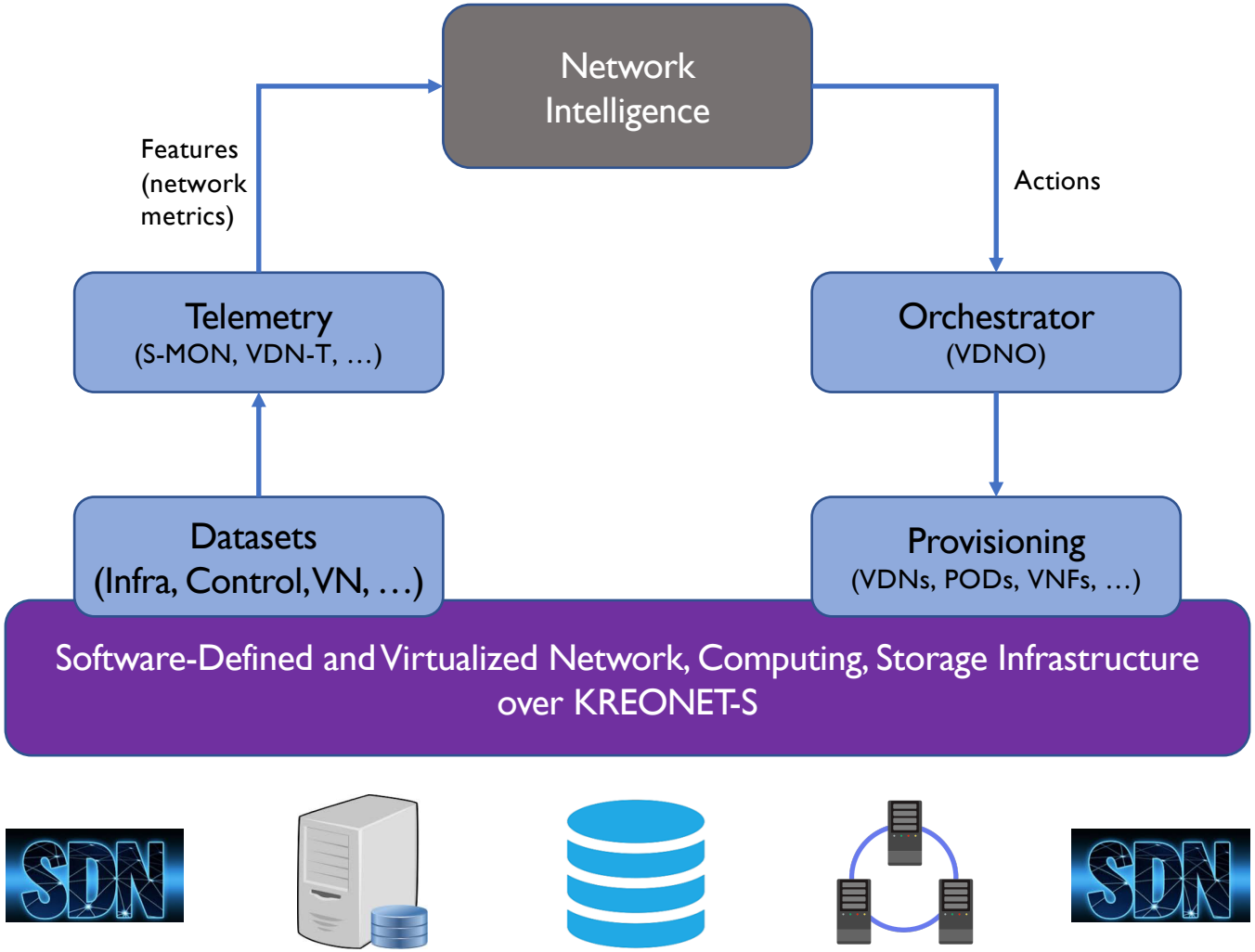
Advanced NREN Collaborations

- 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)

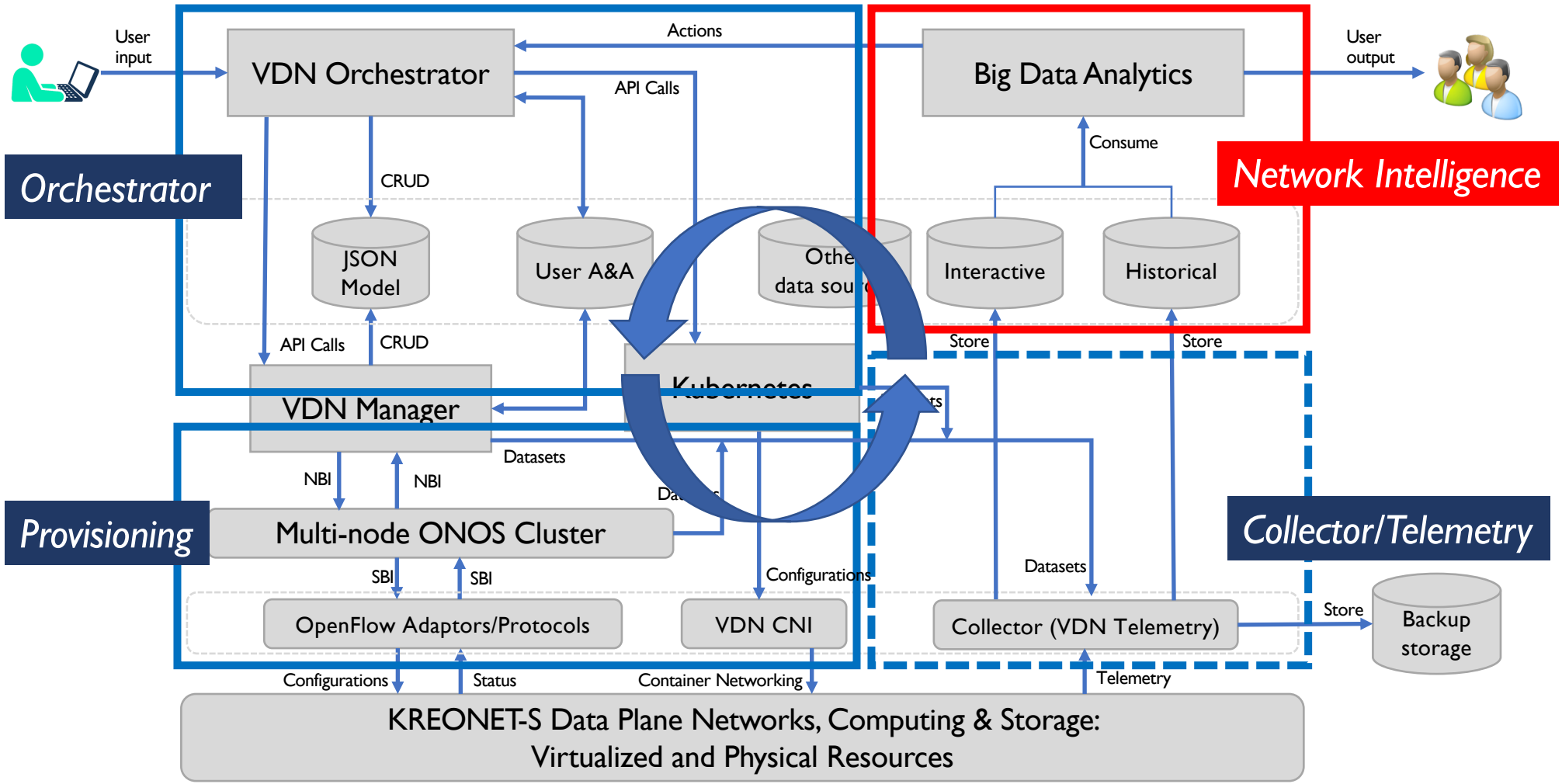


Automated Virtual Networking

NI Control Loop on KREONET-S (1)



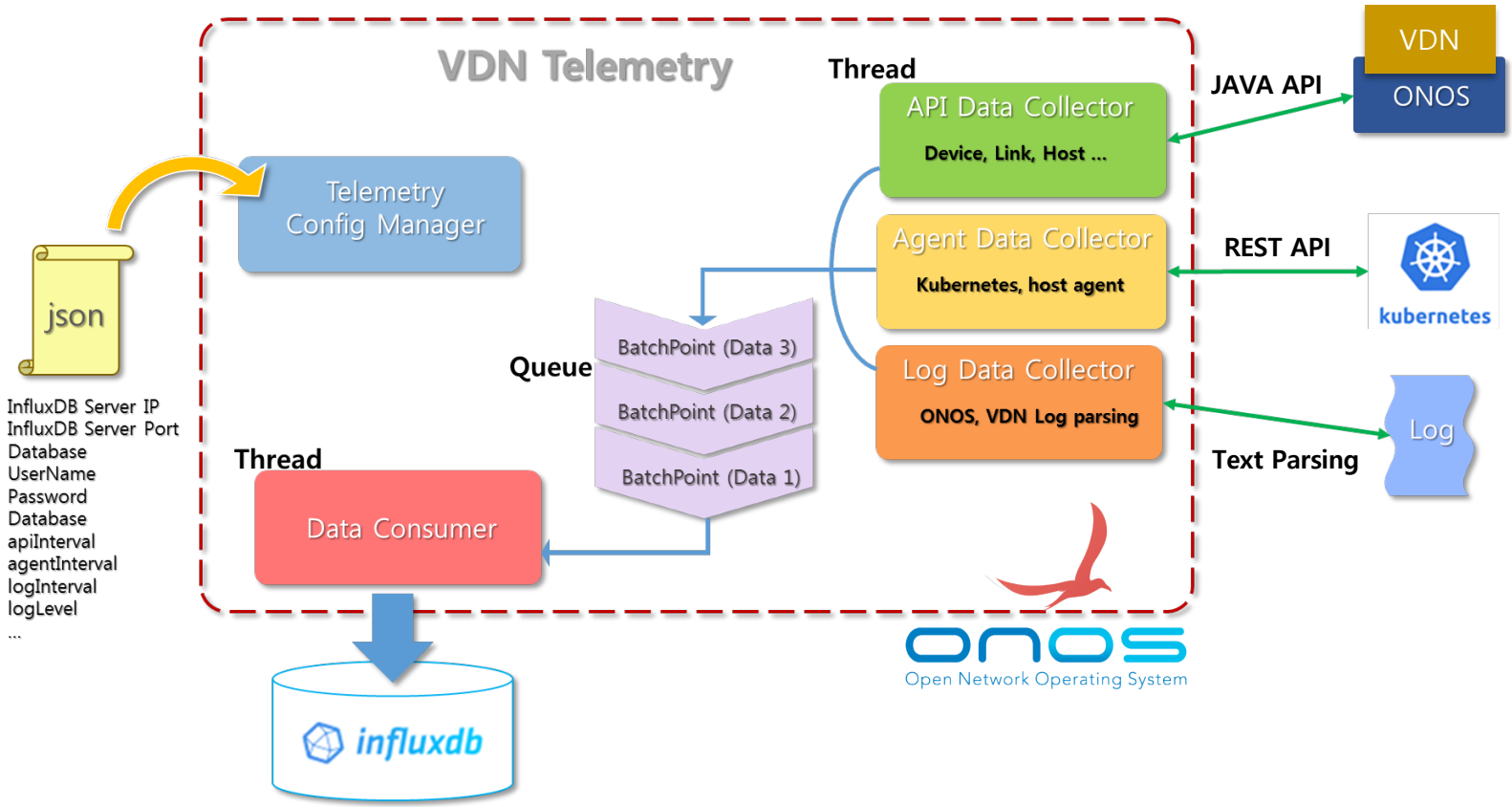
NI Control Loop on KREONET-S (2)



Reference: ESnet6 software automation architecture 2019, Inder Monga/ESNET

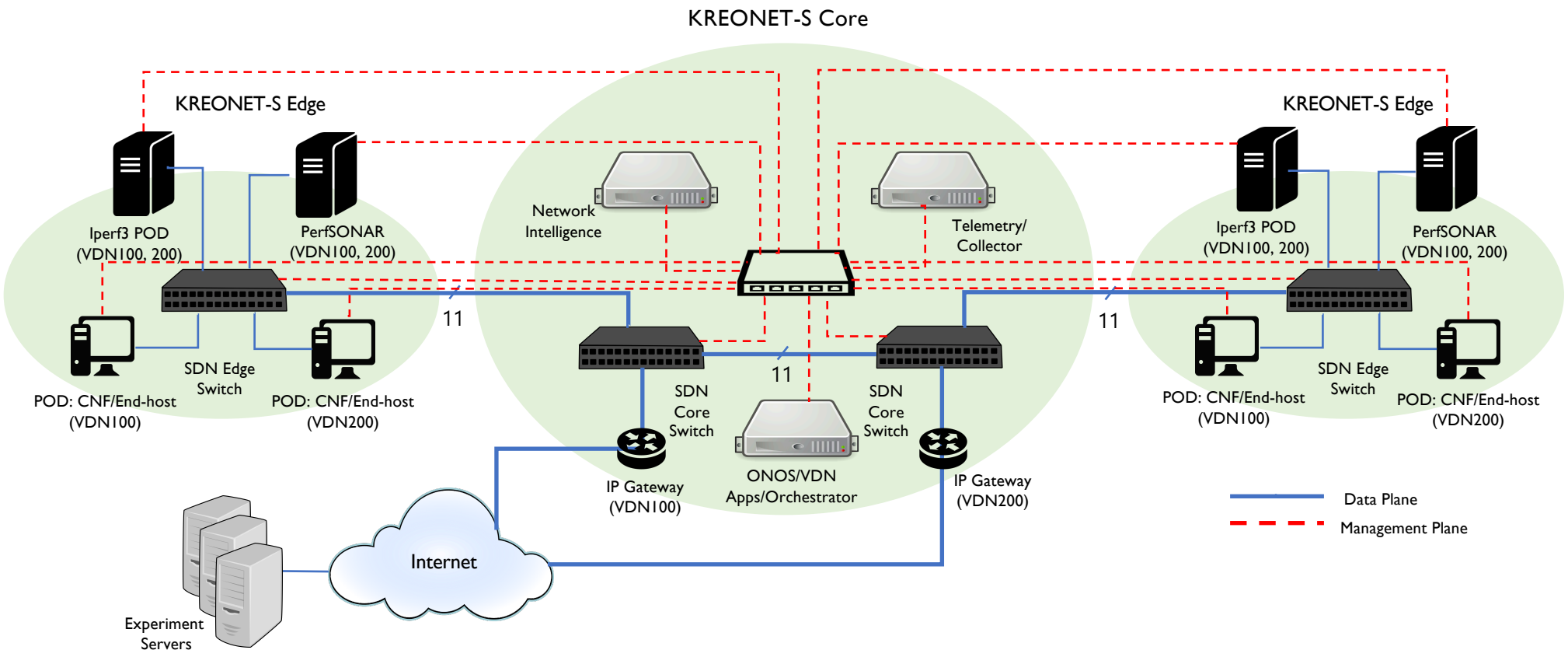
VDN Telemetry

- 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

http://www.kreonet-s.net