Electricity Power Management Utilizing AI in KREONET-S

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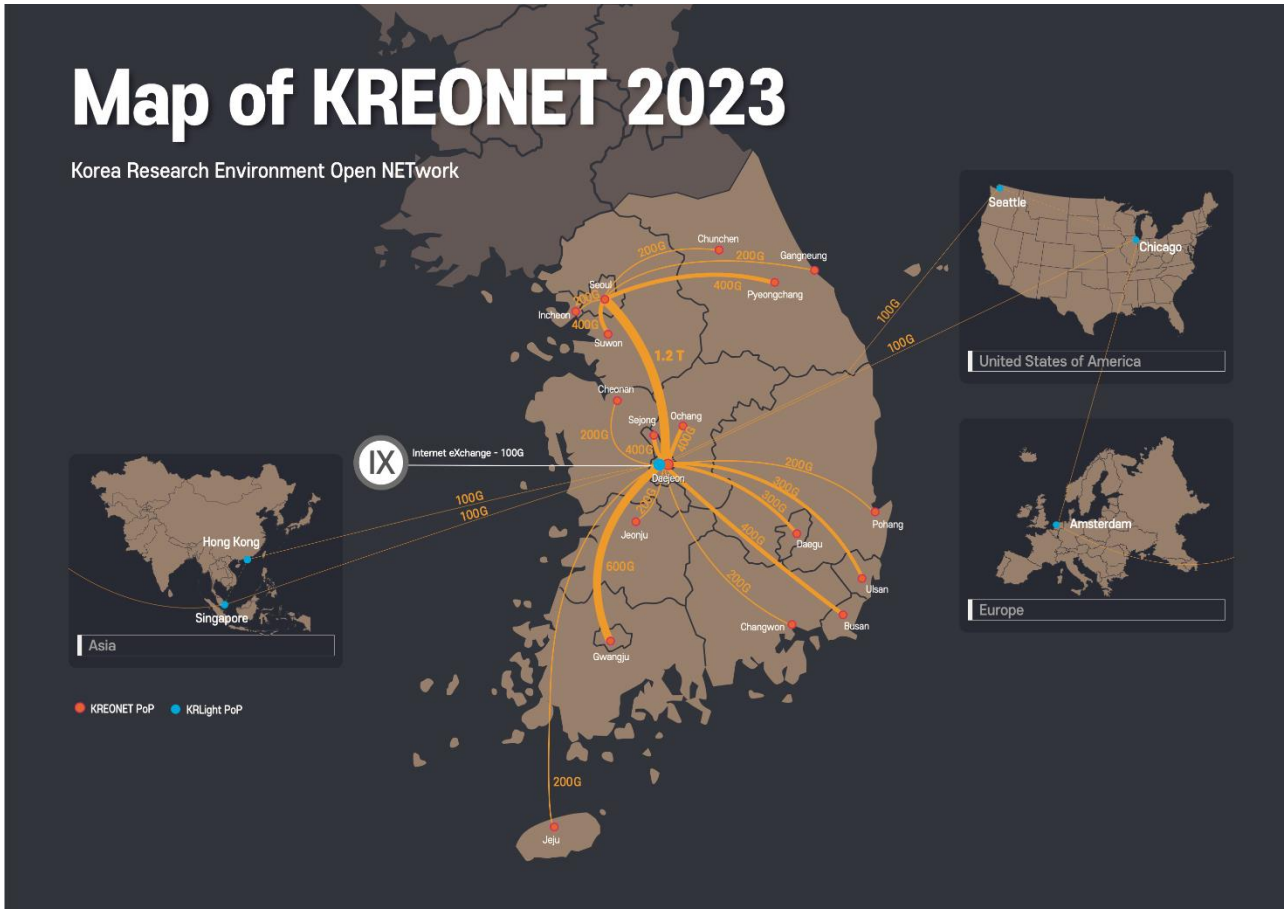
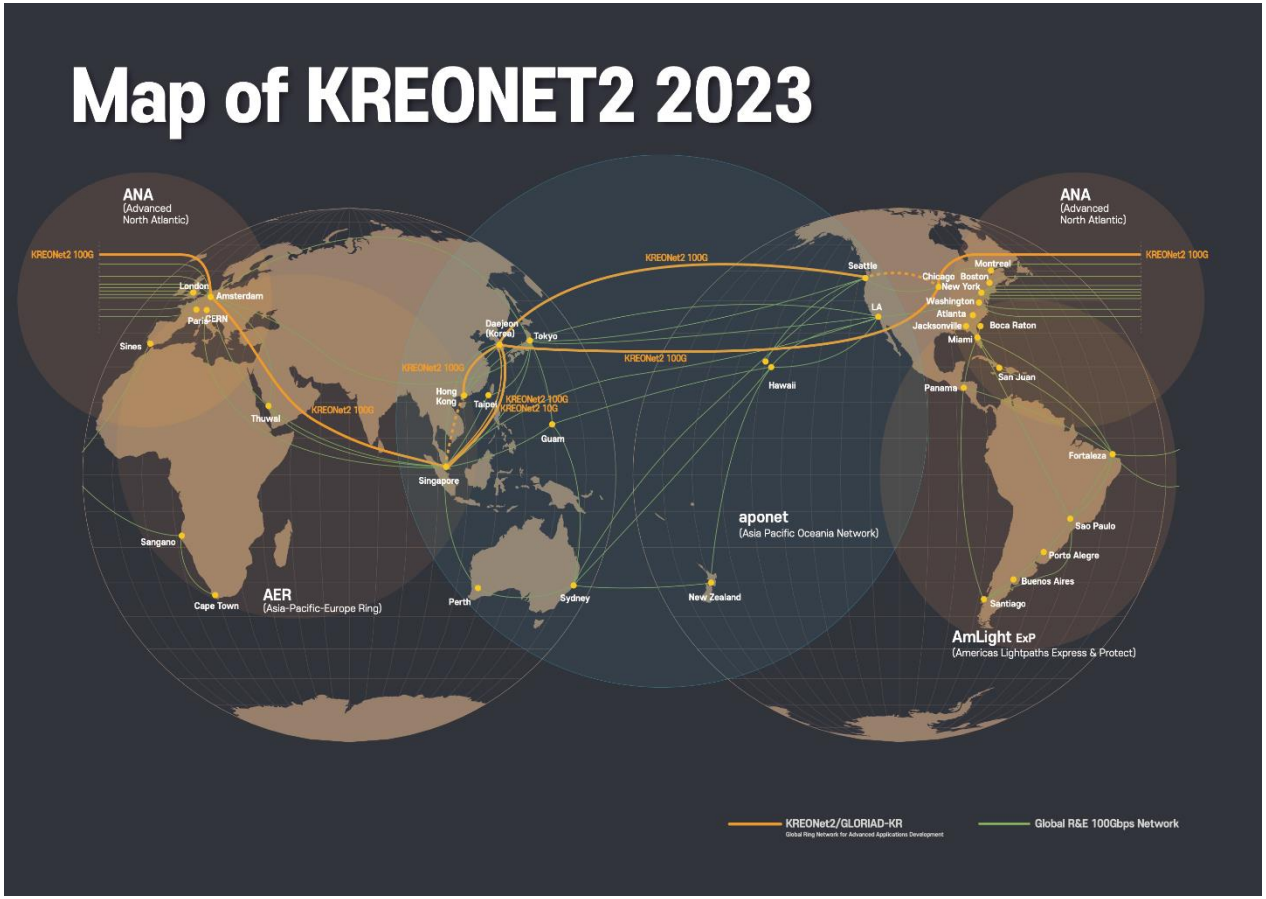
KREONET / KREONET2 Intro.

- KREONET network (domestic)
  - Ring topology (600Gbps per lambda)



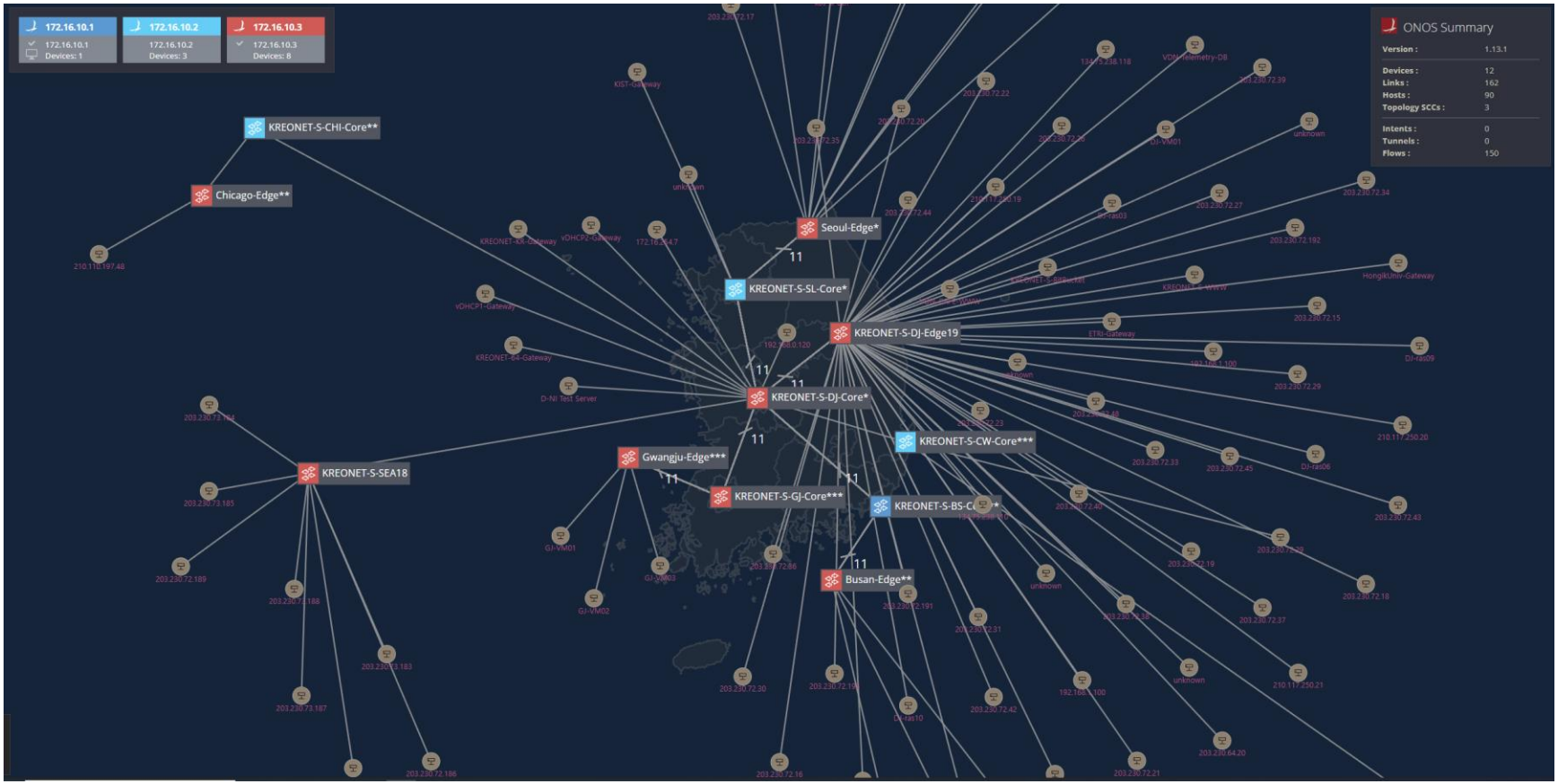
KREONET / KREONET2 Intro.

- KREONET2 network (international)
  - Ring topology (Update: Daejon - Singapore / Singapore - Amsterdam)



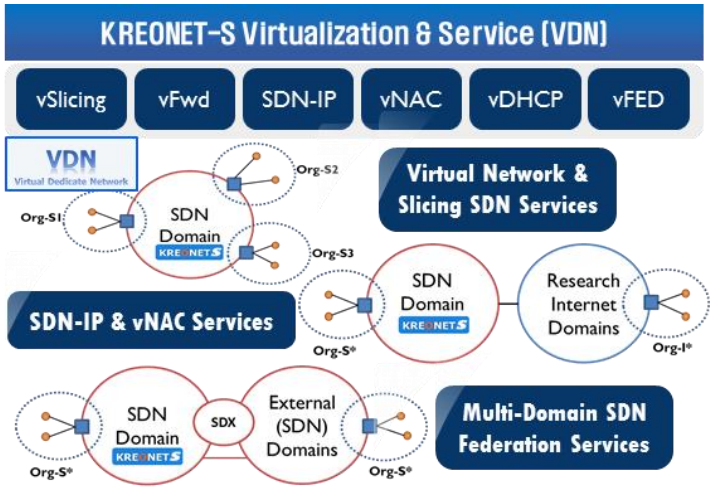
KREONET-S Intro.

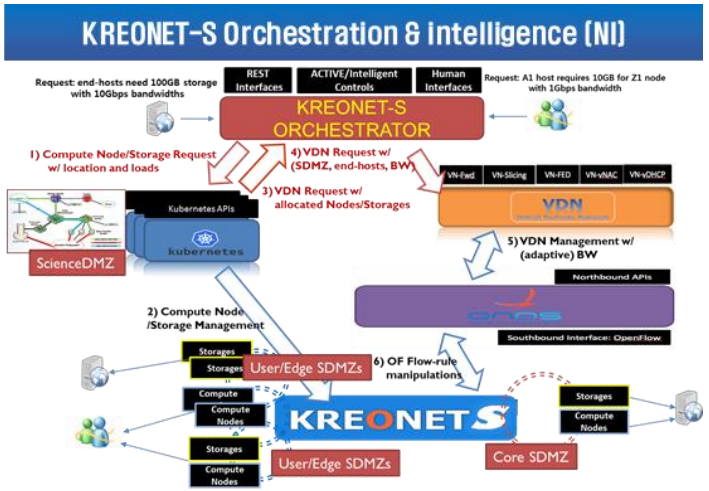
- KREONET-S topology
  - SDN switches in 7 Pops: Domestic(5) / International(2)

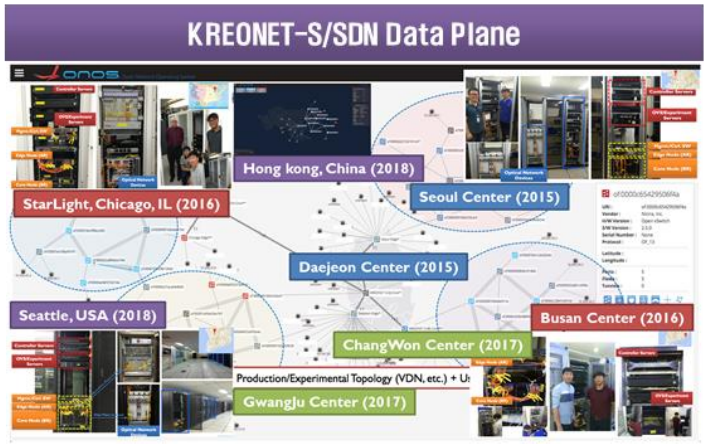


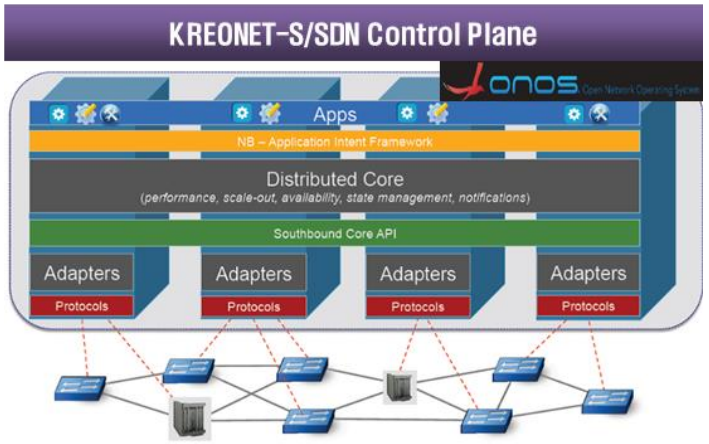
KREONET-S Intro.

- KREONET-S architecture
  - Data plane/ Control plane / Application plane / Orchestration plane



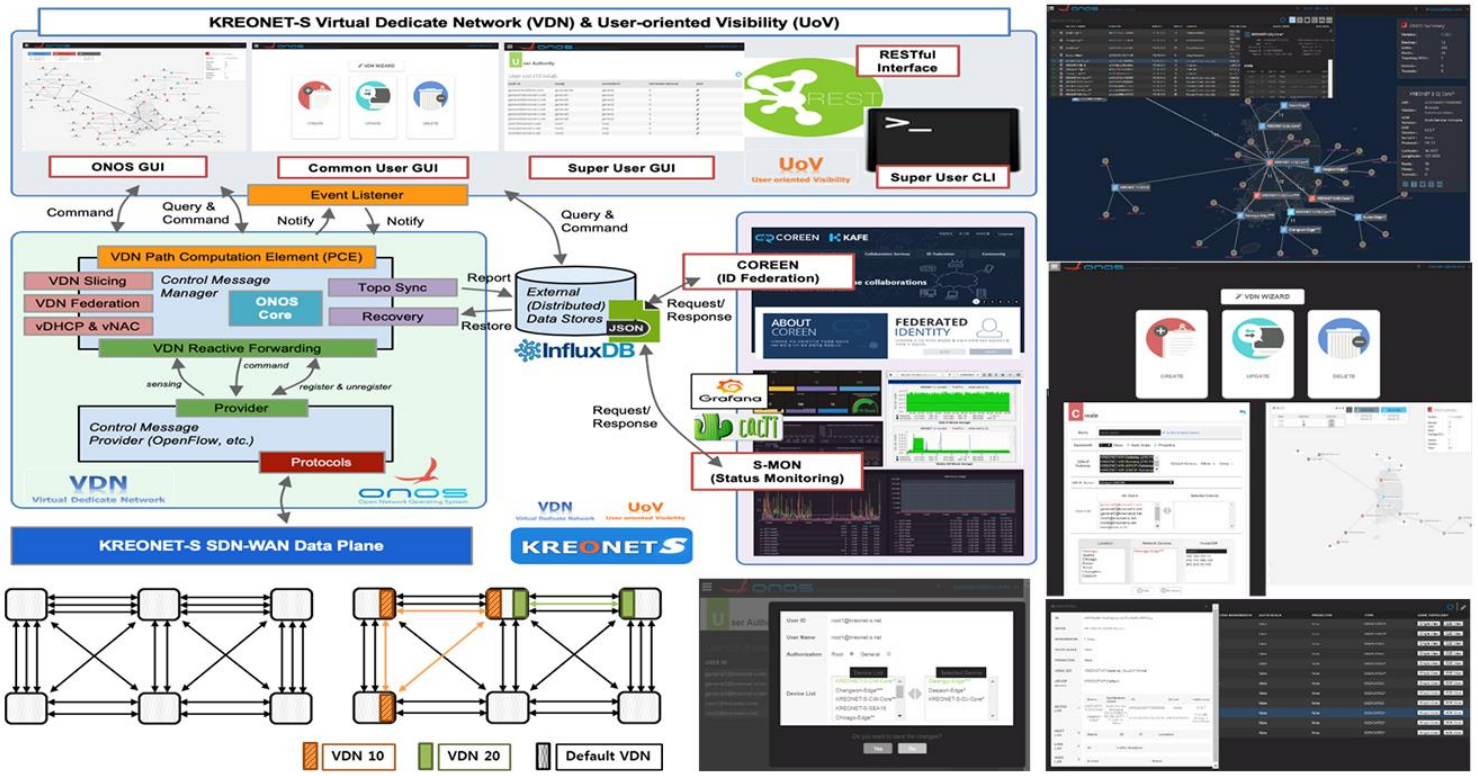






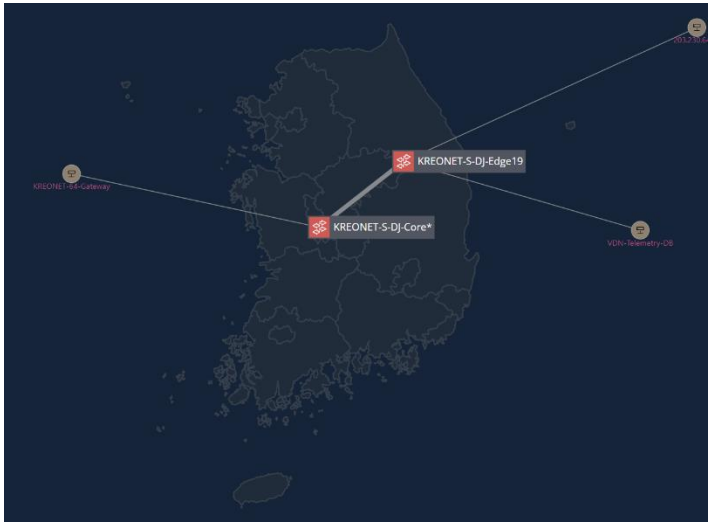
KREONET-S Intro.

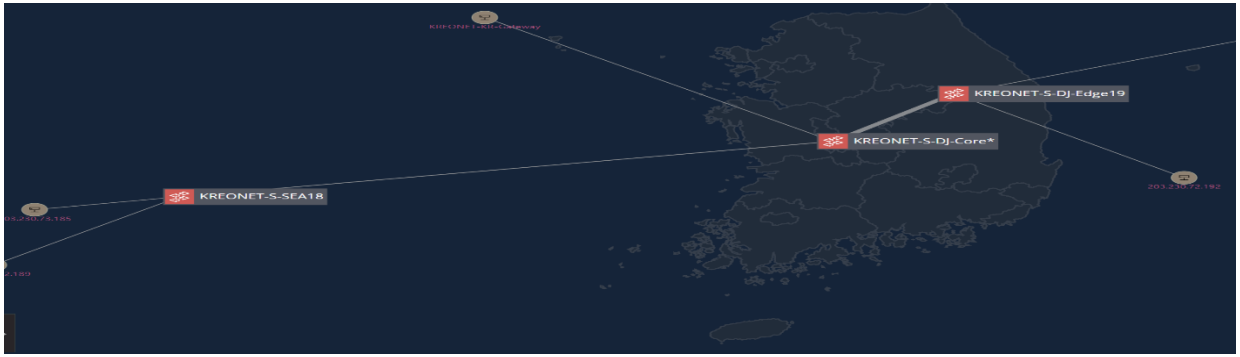
- Virtually Dedicated Network (VDN)
  - User based Dynamic on-demand Virtual network managements



KREONET-S Intro.

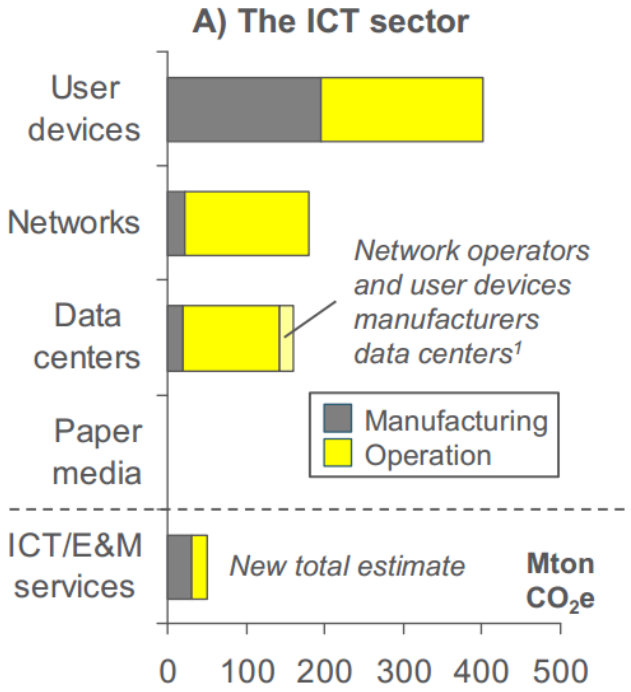
- Virtually Dedicated Network (VDN)
  - Logically isolated and dedicated networking with high performance





Electricity Power Management in KREONET-S

- Network intelligence in KREONET-S
  - Orchestration plane
    - Carbon footprint of networks in the ICT sector
    - SDN-based electricity power management on network operation



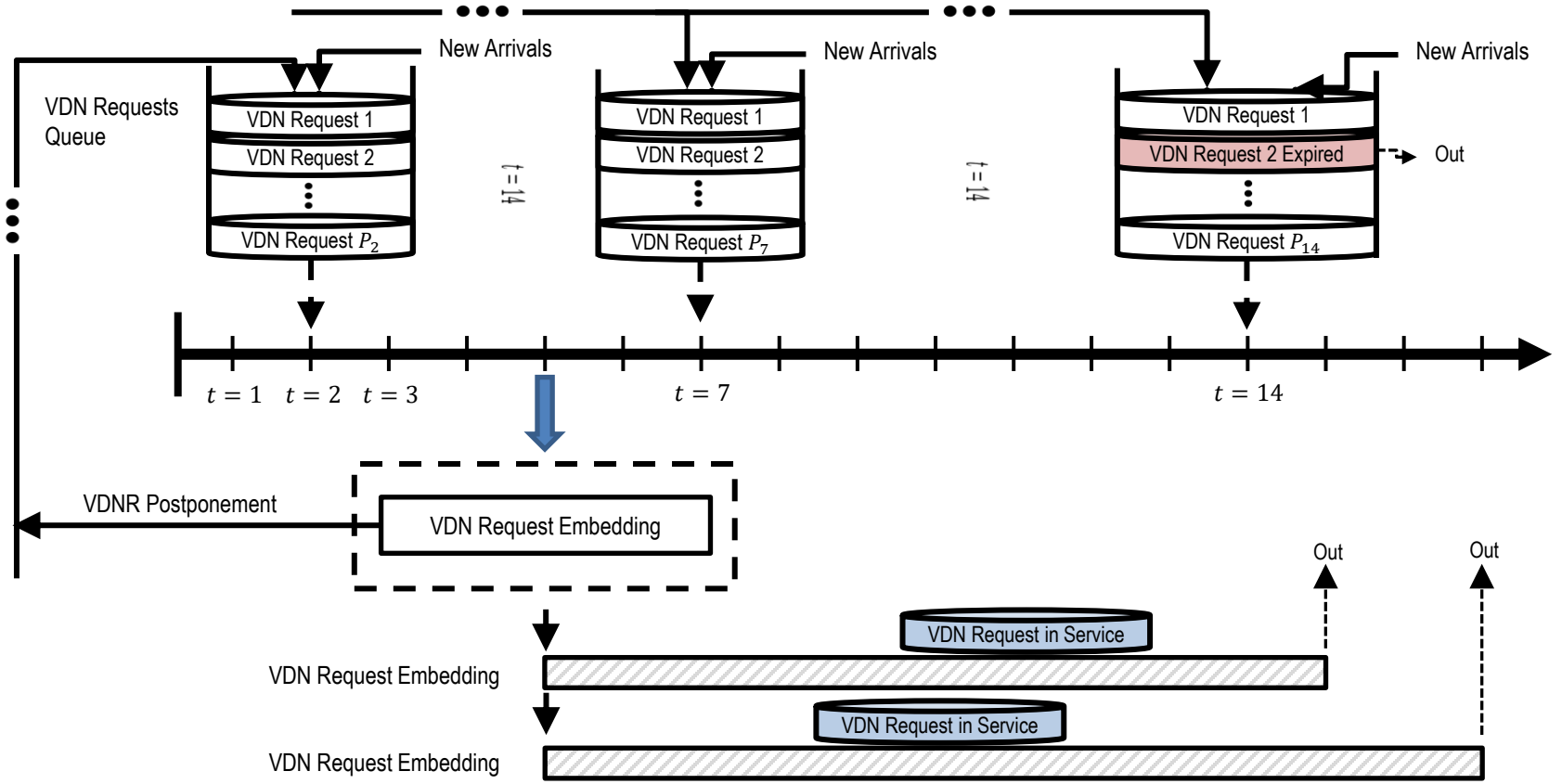
Electricity Power Management in KREONET-S

- VDN(Virtual Dedicated Network) requests
  - Set of hosts
  - Required bandwidth
  - Required service duration
  - Maximum queue delay

- Objective function
  - Minimize energy consumption in KREONET-S (energy efficiency)
  - Satisfying VDN requests (resource utilization)

Electricity Power Management in KREONET-S

- VDN(Virtual Dedicated Network) embedding
  - VDN requests, embedding, and postponement



Electricity Power Management in KREONET-S

- Power consumption model for OpenFlow switches
  - $P_{switch} = P_{base} + P_{config} + P_{control} + P_{OF}$
  - Power consumption of configuration
    - Number of active ports
    - Configured line speed
  - Power consumption of control traffic
    - PacketIn messages
    - FlowMod messages
  - Power consumption of the processed OpenFlow traffic
    - Per each processed packet
      - Number of matches
      - Number of actions
  - Almost independent of the traffic:(P_{OF})

F. Kaup et. al., "Measuring and Modeling the Power Consumption of OpenFlow Swithches"

Electricity Power Management in KREONET-S

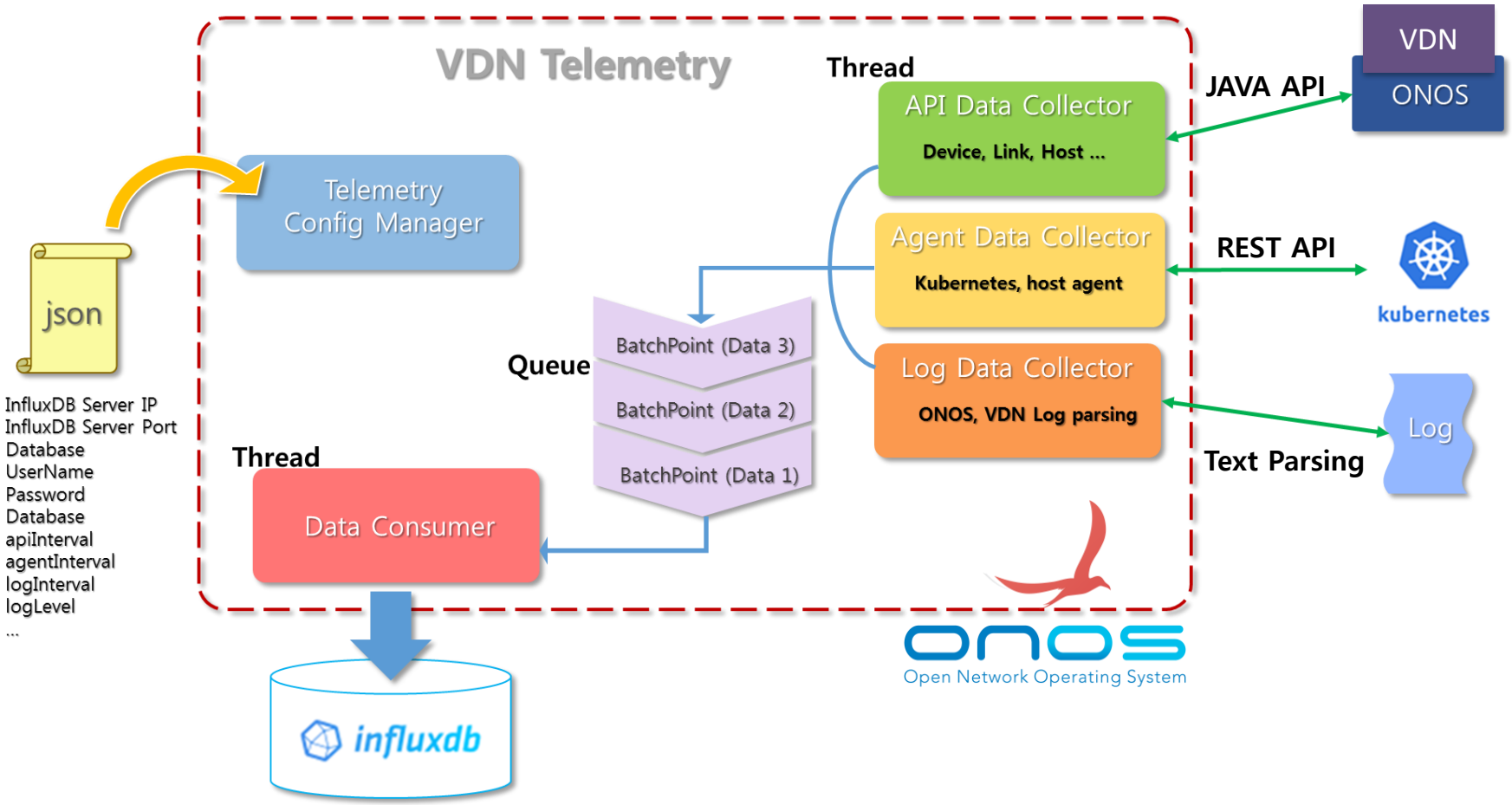
- SDN-based switches in KREONET-S
  - Specifications of Switches
    - 6 Brocade Communications (MLXe-8)
      - Max: 4,060W
    - 3 Arista (DCS-7050SX-64)
      - Typical(50% load): 140W
      - Max: 220W
    - 3 Edge-Core networks (as5712-54x)
      - Max (without pluggable optics): 282W

- References

Charalampou, P. & Sykas, E. D. An SDN Focused Approach for Energy Aware Traffic Engineering in Data Centers. *Sensors Basel Switz* **19**, 3980 (2019).
Assefa, B. G. & Özkasap, Ö. A survey of energy efficiency in SDN: Software-based methods and optimization models. *J Netw Comput Appl* **137**, 127–143 (2019).
Assefa, B. G. & Özkasap, Ö. RESDN: A Novel Metric and Method for Energy Efficient Routing in Software Defined Networks. *Ieee Trans Netw Serv* **17**, 736–749 (2020).
Etengu, R., et. Al., AI-Assisted Framework for Green-Routing and Load Balancing in Hybrid Software-Defined Networking:
Proposal, Challenges and Future Perspective. *Ieee Access* **8**, 166384–166441 (2020).

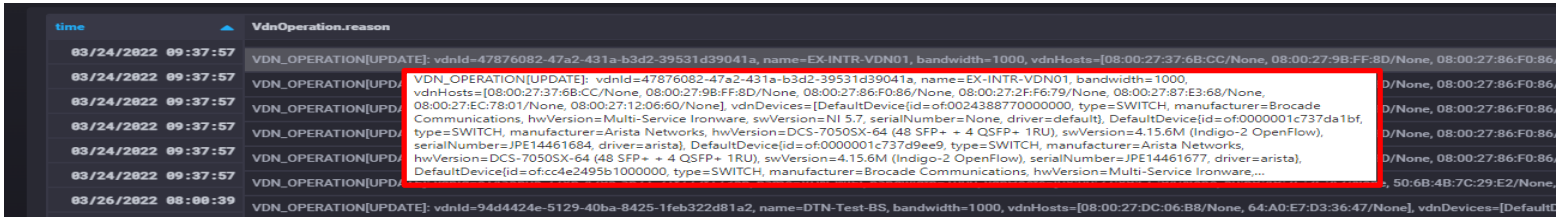
Data acquisition in KREONET-S

- KREONET-S telemetry



Data acquisition in KREONET-S

- KREONET-S telemetry
  - VDN operation (InfluxDB)
    - VDN ID, Bandwidth, VDN hosts, Devices, Links(port), etc.



  - Port states per each device information (REST API)
    - Port ID, isEnabled, port Speed, etc.

Response Body

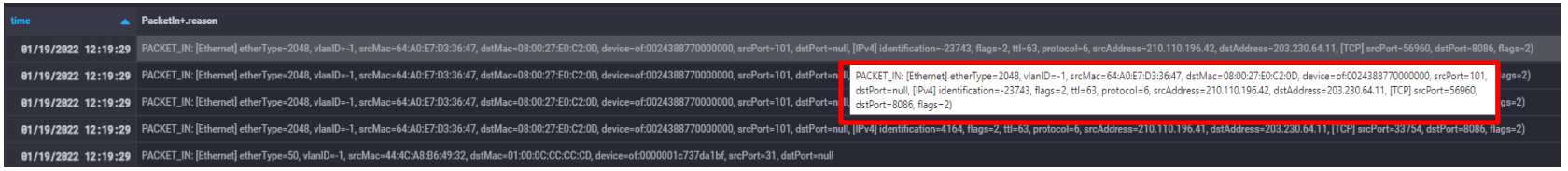

```
},
"ports": [
  {
    "element": "of:0000001c737d9ee9",
    "port": "3",
    "isEnabled": true,
    "type": "copper",
    "portSpeed": 10000,
    "annotations": {
      "adminState": "enabled",
```

Data acquisition in KREONET-S

- KREONET-S telemetry
  - Flow states per each device
    - Flow ID, priority, packets, etc.


```
"id": "281477277096117",
"tableId": 0,
"appId": "org.onosproject.core",
"groupId": 0,
"priority": 40000,
"timeout": 0,
"isPermanent": true,
"deviceId": "of:cc4e249599000000",
"state": "ADDED",
"life": 26012679,
"packets": 3948,
```


  - Processing packets (PacketIn+)
    - srcMac, dstMac, device, srcPort, dstPort, etc.

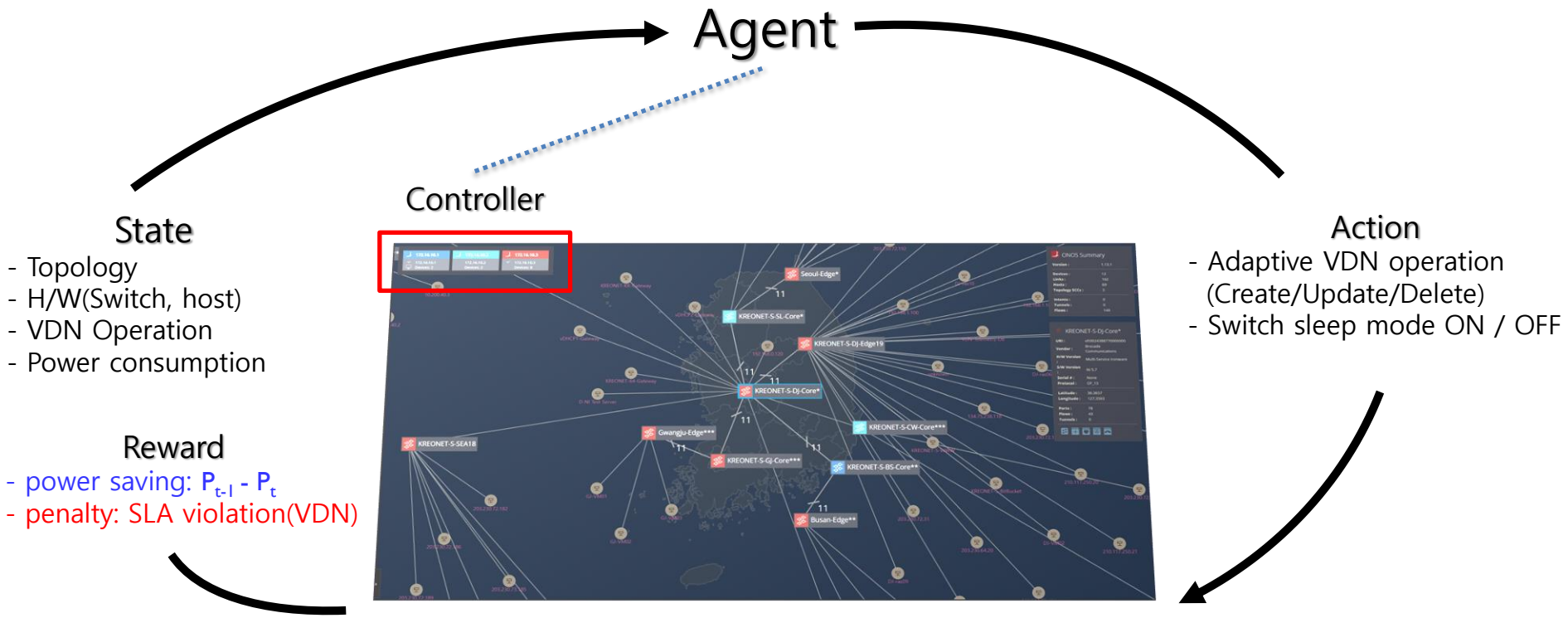


AI algorithm in KREONET-S

- Agile procedure
  - Phase 1. AI based power management model design
    - MDP model definition
    - Applying simple network environment & RL algorithm
  - Phase 2. evaluation using hybrid testbed / simulation
    - Applying complex network environment & service scenario
    - Refinement AI algorithms
      - Designing and applying various AI & DRL algorithms

AI algorithm in KREONET-S

- Reinforcement Learning (RL) based overall architecture

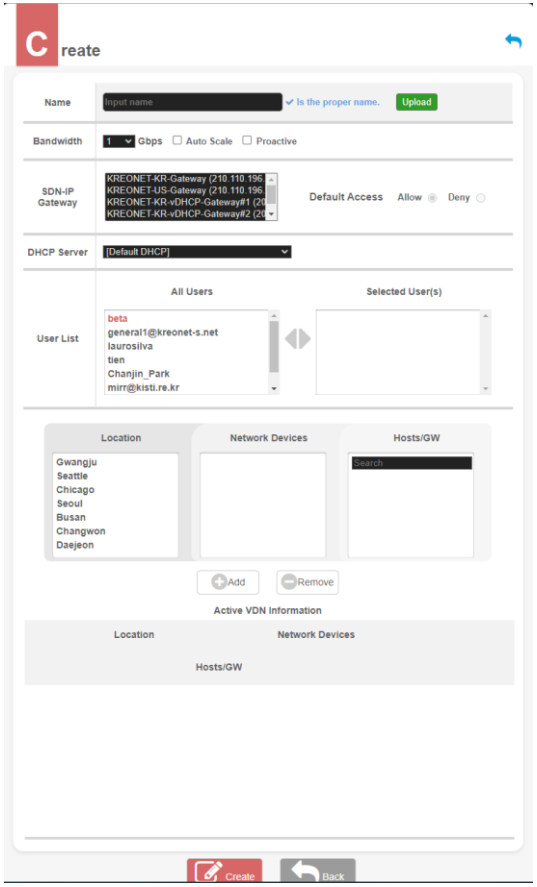


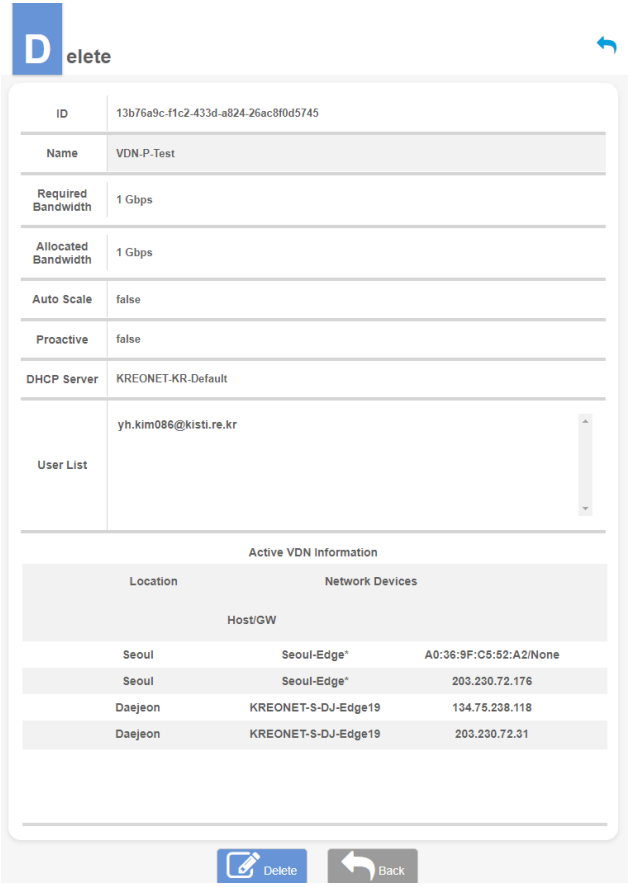
AI algorithm in KREONET-S

- Proposed algorithm in simple environment
  - MDP definition
    - State
      - Port status of switches by time (energy consumption)
      - Status of VDN operation by time
    - Action : adjustable VDN operation (Discrete / Continuous)
      - Create: VDN list X (bandwidth / set of hosts)
      - Update: VDN list X (bandwidth / set of hosts)
      - Delete: VDN list
      - Switch on/off
    - Reward
      - Total electricity power saving by time: $P_{t-1} - P_t$ (P: energy consumption)
      - Penalty(soft): $BW_{required} - BW_{allocated} < 0$ (SLA violation)
      - Penalty(hard): $PT_{used} - PT_{allocated} < 0$(threshold) (PT: Peak Traffic)
  - Development environment (AI algorithm)
    - Tensorflow / Keras(deep learning model) / gym (RL environment)
    - Create custom gym environment

AI algorithm in KREONET-S

- VDN generation using REST API
  - VDN create / delete / update





AI algorithm in KREONET-S

- VDN generation using REST API
  - Queueing system
    - Maximum queue delay
    - Service request rate
    - Service duration
  - Type of VDN service requests
    - High-bandwidth
    - Low-latency
    - Security / connectivity
  - Traffic generation (Ostinato)
    - According to type of VDN requests
      - Traffic volume
      - Traffic pattern

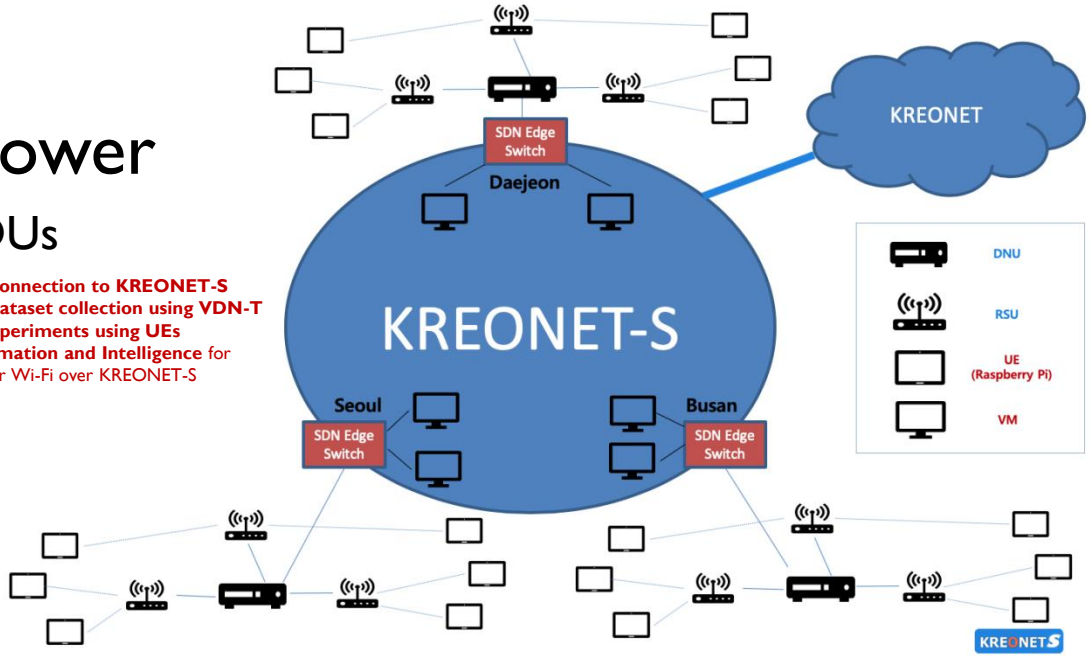
AI algorithm in KREONET-S

- Proposed algorithm
  - Deep Reinforcement Learning model
    - Agent (Discrete / Continuous action)
      - DQN, DDPG, PPO, etc.
    - Neural network model (critic / actor network)
      - RNN(LSTM) layer, Input/output layer, etc.
    - Training parameters
      - Optimizer, learning rate, discount factor, batch size, etc.
- Experiment & validation
  - Hybrid simulation (KREONET-S / simulation environment)

Future works

- Extended network & service scenario
  - Wireless environment (5G, WiFi, etc)
  - Traffic generation with real-time VDN requests
  - Prediction of time-series data (RNN)
    - Traffic usage
    - User requests (VDN)
    - Wireless environments
- Monitoring electricity power
  - Real-time power metering of PDUs

- **UE Connection to KREONET-S**
- **UE Dataset collection using VDN-T**
- **NI experiments using UEs**
- **Automation and Intelligence** for Carrier Wi-Fi over KREONET-S



Thank You!

Questions and/or Comments to
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