KREONET optical network and quantum communication testbed

September 11, 2017

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1. KREONET and Optical Footprint
2. Quantum Key Distribution in KREONET
3. KREONET’s Flexgrid Network Plan
KREONET/KREONet2 (AS1237/AS17579)

- KREONET (Korea Research Environment Open Network)
- Korea’s National Science & Research Network, managed and operated by KISTI since 1988
- GLORIAD-KR, Core Member of GLORIAD project since 2005
- Advanced Research Network in “Utilization and Promotion of National Supercomputing” Act (implemented in 2011 in Korea)
- 17 Domestic Regional GigaPoPs and 4 International GigaPoPs
- 200 connected R&E organizations: National Research Institute and Lab, University, University Hospital, Research Institute of Company, library, Public Sector etc.
- 365*24 NOC (Network Operation Center) Service
- Linking internet exchanges (KT, SKB, Sejoing Telecom) and Clouds (Amazon, Microsoft)
- L1 Lightpath, L2 Carrier Ethernet Service, L3 R&E IP service, VDN based on KREONET-S

KRLight

- GLIF Open Lightpath Exchange (GOLE), managed and operated by KISTI
- Transcontinental GOLE (GLIF Open Lightpath Exchange): Asia – North America - Europe
- Distributed GOLE: Daejeon/KR, Hong Kong/CN, Seattle/US, Chicago/US, Amsterdam/NL
- Integrated with R&E IP network: KREONet2 (AS17579)
<Major Activities>
- KREONET-S (KREONET SD-WAN) Project
- eduroam KR, NRO of Korea
- CERT-KREONET
- Science DMZ, DTN, …

- National-wide 100Gbps National Research Network
- 17 Domestic GigaPoPs, 4 International GigaPoPs
- KREONET Backbone Availability: 99.94%('16)
- KREONet2/GLORIAD Backbone Availability: 99.98%('16)
- User: about 200 national research institutes, universities etc. (500,000 users)
KREONET Optical Network (1) for R&E IP Routed Service

ROADM (100G)

Seoul-Daejeon ROADM Ring

Daejeon-Daegu ROADM Ring

Legend:
- Optical Cable
- KT Regional POP
- Transport Node
- KT Core Transport Node

Incheon 10G
Songdo 10G
Suwon 10G
Gangneung 10G
KISTI Seoul

Cheonan 10G
Ochang 20G
Sejong 20G
Jeonju 10G
KISTI Daejeon

Daegu 30G
Daegu 20G
Pohang 20G
Ulsan 20G
Jeju 10G
Busan 20G
Gwangju 10G

Seoul

Daejeon

Capacity 100G
Capacity 30G

1G 2G 3G 10G 20G 30G 50G 100G
Fully meshed 100G Transportation System covers 5 major cities

Legend:
- Optical Cable
- KT Regional POP
- Optical Transport Node
- KT Core Transport Node
- 1830-SS32
- 1830-SS36
KREONET International Network

<table>
<thead>
<tr>
<th>Cable</th>
<th>Section</th>
<th>Open</th>
<th>Cable distance</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEA</td>
<td>Asia, Europe 13 countries</td>
<td>1997.11</td>
<td>27,943km</td>
<td>10Gbps</td>
</tr>
<tr>
<td>SMW3</td>
<td>Asia, Europe 33 countries</td>
<td>1999.12</td>
<td>39,000km</td>
<td>160Gbps</td>
</tr>
<tr>
<td>CUCN</td>
<td>Pan-asia 5 countries</td>
<td>2000.1</td>
<td>23,438km</td>
<td>80Gbps</td>
</tr>
<tr>
<td>Unity</td>
<td>Japan-US</td>
<td>2010.4</td>
<td>9,620km</td>
<td>7.68Tbps</td>
</tr>
<tr>
<td>APCN2</td>
<td>Asia 8 countries</td>
<td>2001.12</td>
<td>19,000km</td>
<td>21.1Tbps</td>
</tr>
<tr>
<td>FNAL / RNAL</td>
<td>Korea-Japan-Twian-Hong Kong</td>
<td>2002.3</td>
<td>9,748km</td>
<td>5.76Tbps</td>
</tr>
<tr>
<td>TPE</td>
<td>Korea-China-Twian-US</td>
<td>2008.9</td>
<td>19,000km</td>
<td>2.56Tbps</td>
</tr>
<tr>
<td>KJCN</td>
<td>Korea-Japan</td>
<td>2002.3</td>
<td>500km</td>
<td>2.88Tbps</td>
</tr>
</tbody>
</table>
Total Fiber Distance: 80,275 km
= about double length around the earth
GLORIAD (GLObal RIng network for Advanced Application Development) : KREONet2, International Network of KREONET
GLIF (Global Lambda Integrated Facility), 2017

KRLight, OLE (Open Lightpath Exchange)

Linking the world with lambda
=> Global Cyber-infrastructure, supporting Collaborative Scientific R&D project
KRLight, Distributed Open Lightpath eXchange-Korea

- Univ. of Hong Kong
- CERNET
- Microsoft, ASNet, NUS...
- Google (IPv6)
- HKIX
- KREONet2
- TEIN
- CUHK, HARNET, APAN-JP, JGN-X, LHCOPN
- KRLight Topology - May, 2016
  (Buseung Cho, bscho@kisti.re.kr)
  Peering with KREONet2  GOLE (L2 transit)
High Energy Physics & Fusion Energy Science

Enabling Science Discovery
- New particle, “Higgs” in CERN LHC
- Gravitational Wave in LIGO

Bio/Genome Research & Medical Science

Astronomy & Climate Changes

Advanced Scientific Computing Research

Education & e-Culture

Future Internet & Construction
**CERT-KREONET**

- As a National Critical Communication Facility appointed by Ministry of Science and ICT
  - Security Analysis and Evaluation for KREONET Infrastructure
- KREONET user protection
  - Technical Support and response for cyber attack
  - Integrated Support System for Security Control and Automation

**KREONET Additional Service**

- L2VPN-based network integration
  - example) between head-quarter and branch office
- Performance Measurement and Enhancement
  - Troubleshooting for network performance based on PerfSONAR
- NTP-based Time synchronization service
  - NTP: Network Time Protocol
- KREONET DNS IPv4/IPv6
  - Integrated AKAMAI CDN Service, DNS sinkhole

**KREONET High Performance Networking Service**

- Lambda Networking Service (Lightpath)
  - 1:1 bandwidth guaranteed Networking Service
- R&E IP Networking Service
  - General Internet Service
- SDN-based VDN (Virtual Dedicated Network) Service
  - Dynamic Bandwidth on Demand Service by user-controlled for 1G/10G/100G end-to-end path

**Technical Support For advance research**

- Big data transfer
  - Support for 4K/8k Gateway
- High-quality Media transfer
  - Policy and technical support for national eduroam service

**KREONET eduroam Service**

- Building national eduroam service
  - Role as a NRO (National Roaming Operator)
  - Policy and technical support for national eduroam service
- Promotion for eduroam service
  - Assignment RO for High educational sector (University) : Chonnam National University
  - Assignment RO for other sector (public...)

**KROENET e-conferencing Service**

- Software-based e-conferencing System
  - Vidyo
- Hardware-based e-conferencing System
  - Cisco MSE800, Telepresence System
- All KREONET users can use

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**KREONET**

- eduroam Service
- e-conferencing Service
- High Performance Networking Service
- Additional Service
- Technical Support For advance research
High Vendor Dependency
(Vendor Lock-in)
Inability to scale
Distributed Control

Open Source (Vendor Neutral)
High Scalability
Central Control
Virtualization
Saving CapEX/OpEX

KREONET Softwarization (KREONET SD-WAN)

Legacy Network

KREONET-S® Applications & Services: New User Services & Experiences (High Performance, Advanced Security)

KREONET-S® Control Infrastructure: Carrier-grade High Availability/Failover and Scalability

KREONET-S® Network Infrastructure: Multi-vendor and Multi-layer to CapEX/OpEX Savings

Production-level SD-WAN Deployment

Developing application(service) software

Setting up the central control plane (OS)

Building the SD-WAN infrastructure
KREONET-S Infrastructure (6 Sites)

StarLignt, Chicago, IL
KREONET Seoul center, KR
KREONET Daejeon Center, KR
KREONET Busan Center, KR
KREONET Gwangju Center, KR
KREONET Changwon Center, KR
KREONET-S VDN (Virtual Dedicated Network) Development

- Bandwidth on Demand by user
  create end-to-end dedicated network by researcher & scientist

- Easy-to-Use User Interface
  Simple and Rapid: several-click Easy, ms Fast

- User-oriented Network Visualization and Monitoring
  Virtual Network Topology and Operational Attributes

![Global Topology View]

![VDN Manager: Main Screen]

![User-oriented Visibility: E2E & Whole VDN Topology Views]

Time-to-Research & Time-to-Collaboration
Use Case: VDN & SDN-IP

- SDN Connectivity
- Internet Connectivity
- SDN-to-Internet Connectivity
- Inter-SDN Connectivity
- IP Routed Paths
- SDN-IP Paths

International Connections (1-hop)

Connections to Service GWs (1-hop)

VDN-100 + SDN-IP

KREONET-S USA

KREONET-S Korea

VDN-200 + SDN-IP

Internet Domain in USA

Internet Domain in Korea

Internet Domain in Korea
Optical Transfer Testbed of Time and Frequency

Atomic clock

RF, Optical carrier, 1 PPS

Laser → Actuator

AOM
Delay line
RF circuit

Partial reflector

Bidirectional Single-core fiber

Partners
- KISTI (Korea Institute of Science and Technology Information)
- KRISS (Korea Research Institute of Standards and Science)
- KASI (Korea Astronomy and Space Science Institute)
KVN & e-KVN (e-VLBI Network in Korea)

- e-KVN: Korean e-VLBI(electronic Very Long Baseline Interferometry) Network
- Real-time e-VLBI observation with real-time correlation between observatory

Yonsei Astronomy Observatory

Daejeon Correlation Center

KVN Tamna

KVN Ulsan

JIVE

Tamna Astronomy Observatory

Ulsan Astronomy Observatory

KREONET

40G (+1G)

100G

40G (+1G)

100G

10G (+1G)

10G (+1G)

10G (+1G)

AARNET
2. Quantum Key Distribution in KREONET
SKT QKD system is based on ATCA (Advanced Telecommunication and Computing Architecture) and easily extend the capacity of encrypted data by adding encryptor slots. Additionally, SKT is developing more flexible platform like QKD server only, etc.

Overview of QKD system

SKT QKD system is based on ATCA (Advanced Telecommunication and Computing Architecture) and easily extend the capacity of encrypted data by adding encryptor slots. Additionally, SKT is developing more flexible platform like QKD server only, etc.

<SK Telecom’s quantum cryptography system>

<table>
<thead>
<tr>
<th>Shelf (ATCA compatible)</th>
<th>Chassis size</th>
<th>19 inch, 12U (14 slot) / 6U (6 slot); Shelf supplier dependent</th>
</tr>
</thead>
<tbody>
<tr>
<td>QKD unit</td>
<td>2 slot</td>
<td></td>
</tr>
<tr>
<td>10Gbps encryptor unit</td>
<td>1 slot (bidirectional 4 ch.) * Max 80 slot (800Gbps)</td>
<td></td>
</tr>
<tr>
<td>Quantum key distribution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secure key rate</td>
<td>&gt; 10 kbps @ 50km</td>
<td></td>
</tr>
<tr>
<td>Protocol</td>
<td>BB84 with unique phase modulation + decoy protocol and modified Winnow error correction</td>
<td></td>
</tr>
<tr>
<td>Random number generator</td>
<td>High speed quantum random number generator (2 Gbps)</td>
<td></td>
</tr>
<tr>
<td>Encryption</td>
<td>10 GbE, STM64 *(10 G SONET/OTN, 40G/100G Ethernet/OTN planned to be provided)</td>
<td></td>
</tr>
<tr>
<td>Algorithm</td>
<td>AES-GCM or LEA-GCM (※LEA: Korean Symmetric Crypto Algorithm)</td>
<td></td>
</tr>
<tr>
<td>Latency</td>
<td>&lt; 10 microseconds</td>
<td></td>
</tr>
<tr>
<td>Random number generator</td>
<td>Quantum random number generator</td>
<td></td>
</tr>
</tbody>
</table>
QKD system: Classical Vs. Quantum cryptography

QKD (Quantum Key Distribution) is the strongest protection method from eavesdropper’s attack.

**Existing Cryptography System**
- Using mathematical complexity to generate key
- Possibility to crack the code rises as the computing power is increased

**Quantum Cryptography System**
- Using quantum phenomenon to generate key (uncertainty principle, no cloning theorem…)
- Auto sensing eavesdropper's attack
- Attempt to take quantum key increase bit error rate

Using large number of photons cannot recognize eavesdropping

Using single photon can recognize eavesdropping
QKD Testbed of Korean government by SKT

SKT and Korea government launched QKD national testbed with 5 locations in Bundang SKT R&D center network and Daejeon national R&D center(KISTI) network

Present

Bundang (SKT)
- Total 17.8Km: Seong-nam Center
- Total 53Km: Su-won Center
- Total 68Km: Yong-in Center
- Total 107Km: Yang-pyung Center

(This is not for real data traffic)

Daejeon (KISTI)
- A → B → A → C
- E → A → C → D
- Total 11Km

(This is for real data traffic)

Future (~19.5)

- Developing long distance QKD (Trusted Node): ~end of ‘17
  ※ current distance limit of QKD: 80km ~ 100km
- Trusted Node support Add/Drop of keys and NxN network
  ※ Currently end to end

SKT

KISTI

Metro area

Metro area

200Km

Trusted Node
QKD Network on KREONET

1st phase ('16)

2nd phase ('17)

Satellite Data

10Gbps

Genome Data

10Gbps
3. KREONET’s Flexgrid Network Plan

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**Fixed Grid (WDM)**

- Optical signals are arranged on a fixed-spacing (50GHz)
- The same modulation format for the same bitrate regardless of the transmission distance
- The demand can occupy less than a fully wavelength capacity

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**Flexible Grid**

- The required minimum resources are allocated adaptively based on traffic demand and network conditions.
- The optical spectrum is divided into small-sized spectrums (slice).

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Flexgrid Network Technology

- **FlexGrid Network on KREONET**
  - **KREONET Roadmap**
    
    | KREONET INFRA | 2016 | 2017 | 2020 |
    |----------------|------|------|------|
    | **Backbone**  | Major service areas 100G (Tot. 600G) | Major service areas 100G (Tot. 600G) | TB networking service |
    |                | ScienceDMZ trial service | ScienceDMZ expanding service area | TB ScienceDMZ (Science Freeway) |
    | **Access**     | 1G/10G expanding service area | 10G upgrading service | 100G/500G expanding service areas |
    |                | 40G/100G trial service | 40G/100G expanding service areas | |

- **Current Situation**
  - Large traffic requirement vs. limited infrastructure investment

- **Benefits**
  - High spectrum efficiency: improve 5 ~ 95% compared to WDM
  - Reduce CAPEX and OPEX
  - Flexible granularity aggregation: sub-channel, super-channel
  - Rate adaptive: Adaptive to actual user traffic volume
  - Distance adaptive: Adaptation to physical conditions on the route
Phase 0: Flexible Network Simulator

- Main features
  - Event driven simulation of State-Full Path Computation Element (PCE)
  - Lightpath requests: Poisson arrival process
  - Service time: exponential probability distribution
  - Spectrum continuity constraint and contiguity constraint
  - IO module for easy topology description including nodes, links
KREONET's Flexgrid Network Plan

- **Phase 1: Flexgrid Network Testbed on SuperSIREN**
  - Currently according to user’s requirement, then allocate fiber cores
  - Test the availability of flexgrid network

- **Phase 2: Deploy Flexgrid Network on KREONET**
  - Expand to lastmile network on KREONET
  - Manage stable and reliable operation

- **Phase 3: Provide Dynamic Resource Provisioning**
  - Flexible spectral resources controlled by KREONET SDN Controller
  - Integrate with KREONET SDN and provide flexgrid networking service
KREONET’s Flexgrid Network Plan

■ Phase 1: Flexgrid Network Testbed on SuperSIREN
  • KREONET’s owned regional optical fiber network
  • High Performance Regional Network in Daejeon Science Town

- Deploy flexgrid network testbed
  - Fiber cores owned by KREONET
  - 1st stage: KISTI ~ KAIST
  - 2nd stage: Expand to all SuperSIREN
- Test the availability of flexgrid network
KREONET’s Flexgrid Network Plan

- Phase 2: Deploy Flexgrid Network on KREONET
  - Expand to lastmile network on KREONET
  - Manage stable and reliable operation
Phase 3: Provide Dynamic Resource Provisioning

- Flexible spectral resources controlled by KREONET SDN Controller
- Integrate with KREONET SDN and provide flexgrid networking service

• KREONET VDN (Virtual Dedicate Network)
  - Virtual Private & Bandwidth-guaranteed Network
• Integrate with VDN
  - Provide dynamic and flexible network including spectral resources
Thank you.
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