NETS: JUNO2:
Resilient Edge Cloud Designed Network (RECN)

October 11, 2019

Tarek Saadawi
Kazuya Tsukamoto
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Project Members

City University of New York, City College (CCNY), USA

Professors:

- **Akira Kawaguchi (Co-PI)**
- **Myung Lee (Co-PI)**
- **Abbe Mowshowitz (Co-PI)**
- **Tarek Saadawi (PI)**

Kyushu Institute of Technology (Kyutech), Japan

Professors:

- **Takeshi Ikenaga**
- **Kenji Kawahara**
- **Kenichi Kourai**
- **Daiki Nobayashi**
- **Masahiro Shibata**
- **Kazuya Tsukamoto (Co-PI)**
- **Masato Tsuru**

* Names are in alphabetic order

Objectives

The objective of the RECN Group is to conduct between the two Institutions collaborative and foundational research on a resilient edge cloud designed network to achieve basic understanding of the underlying science for future RECN.

This work will cover issues of security, heterogeneity, resource constraints and potential mobility of end devices/sensors. A backbone network will be implemented and diversity of access network technologies, availability/placement of computing resources and Quality of Service (QoS) requirements will be examined.

The RECN Group will focus on two key challenges:

1) **Architecture, Resource access, virtualized adaptable computing and networking, network security, and distributed database using hypercube, (first 4 tasks).**
2) **Real-life, emulation and simulation of large scale Internet of Things (IoT) with application to smart grid (this is highlighted in the "Testbed Experiments" section)**

Communications

Regular Communications

- **Monthly Meeting with Video Conference**
- **Created a mail list for all team members**
- **Set up a file server**

Visits

- **Pre-award meeting in Japan (June 2018)**
- **Kyutech visit to CCNY (March 2019)**
- **CCNY visit to Kyutech (September 2019)**
- **Kyutech visit to CCNY (Early March 2020)**

Kyutech Campus (June 2018)

Pre-Award Meeting, Kyutech, Japan

CCNY Campus (March 2019)

Kyutech Campus (September 2019)

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Accomplishments

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- Keynote
  - T. Saadawi, “Secure Resilient Edge Cloud Designed Network,” INCoS 2019
- Journal
  - T. Saadawi , A. Kawaguhi, M. Lee, A. Mowshowitz, “Secure Resilient Edge Cloud Designed Network,” IEICE Transactions on Communications, accepted (invited paper)
- International Conference
  - 22 papers
- International Workshop
  - 7 papers
  - JUNO2 session in WIND 2019
- Local Workshop in Japan
  - 17 papers

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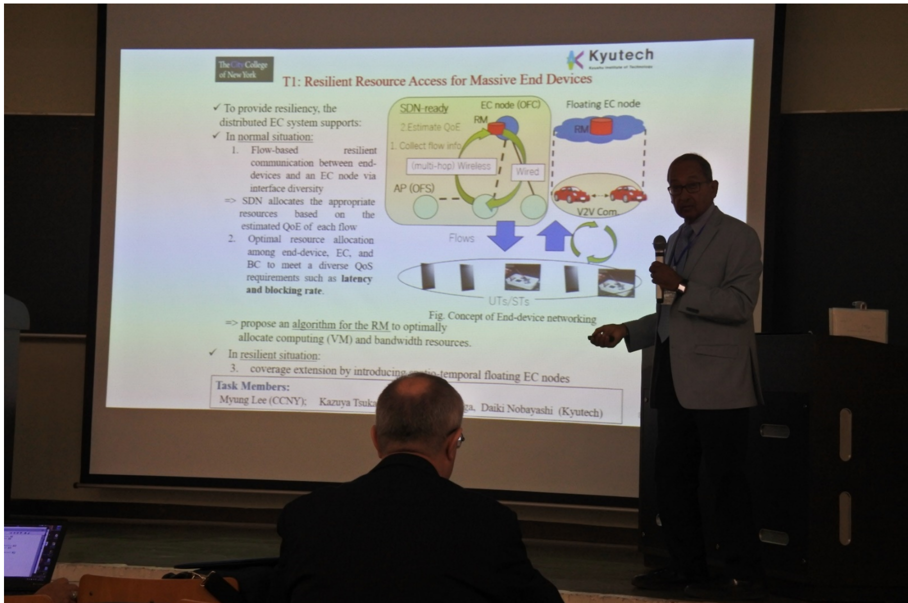
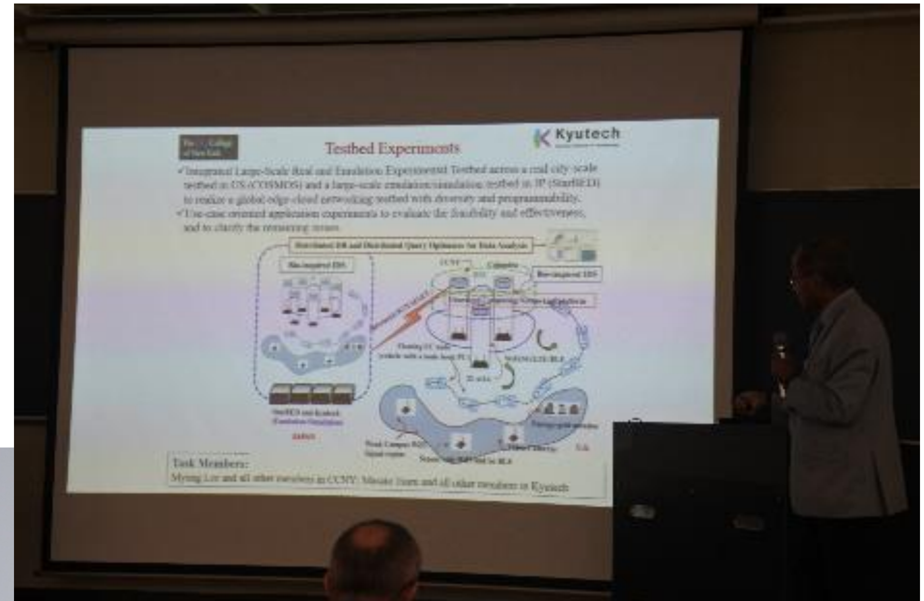
Keynote at INCoS/NBiS 2019





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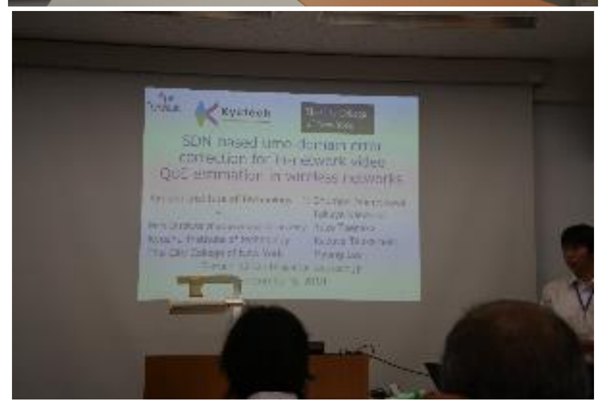
WIND 2019: JUNO2 Session

Kyutech
Kyushu Institute of Technology

- Prof. Myung J. Lee

- Kyutech students

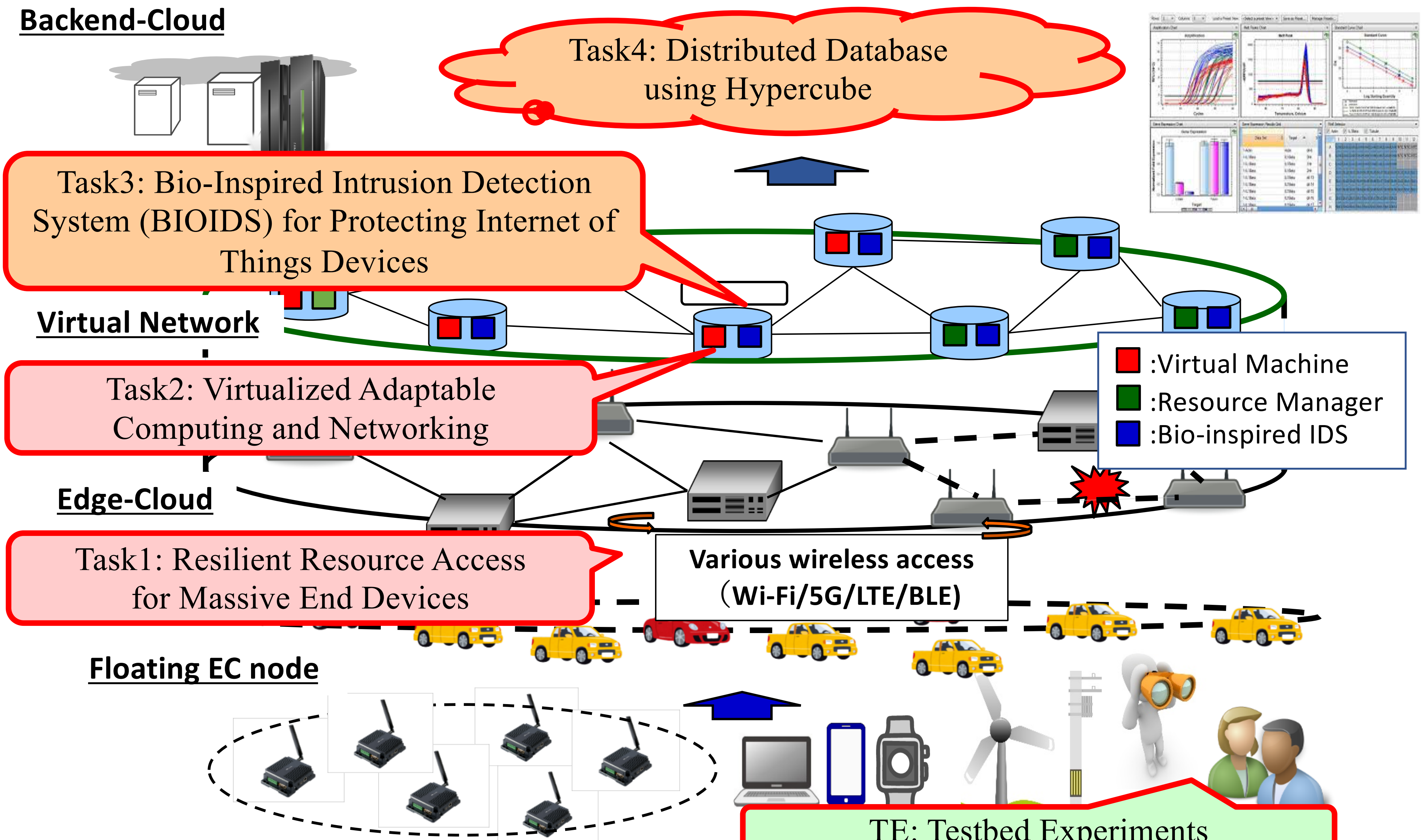


Awards

- EIDWT 2019 Best Paper Award
  - N. V. Ha and M. Tsuru, “TCP with Network Coding Performance under Packet Reordering”
- DASC 2019 Best Paper Award
  - T. Morikawa and K. Kourai, “Low-cost and Fast Failure Recovery Using In-VM Containers in Clouds”
- WIND 2019 Best Paper Award
  - S. Shimokawa, T. Kanaoka, Y. Taenaka, K. Tsukamoto, M. Lee, “SDN-based Time-domain Error Correction for In-network Video QoE Estimation in Wireless Networks”

Best Paper Award in INCoS/NBiS 7 Workshops

Overview of RECN



Tasks

- **TASK 1: RESILIENT RESOURCE ACCESS FOR MASSIVE END DEVICES**

  Task Members: **Myung Lee** (CCNY), **Kazuya Tsukamoto**, Takeshi Ikenaga, Daiki Nobayashi (Kyutech)

- **TASK 2: VIRTUALIZED ADAPTABLE COMPUTING AND NETWORKING**

  Task Members: **Masato Tsuru**; Kenichi Kourai; Kenji Kawahara; Masahiro Shibata (Kyutech), **Akira Kawaguchi**; Abbe Mowshowitz (CCNY)

- **TASK 3: BIO-INSPIRED INTRUSION DETECTION SYSTEM (BIOIDS) FOR PROTECTING INTERNET OF THINGS DEVICES**

  Task Members: **Tarek Saadawi** (CCNY), **Kenichi Kourai** (Kyutech)

- **TASK 4: DISTRIBUTED DATABASE USING HYPERCUBE**

  Task Members: **Abbe Mowshowitz**, Akira Kawaguchi (CCNY); Masato Tsuru, **Shibata Masahiro** (Kyutech)

- **TESTBED EXPERIMENTS**

  Task Members: **Masato Tsuru (Kuytech), Myung Lee (CCNY)** and all team members

  Test scenarios:
  1) Safety by facial recognition.
  2) Managing a distributed electric power grid based on designed hypercube network
  3) Examples of previous tasks
  4) Blockchain for cooperative IDS's

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T1: Resilient Resource Access for Massive End Devices

- ✓ To provide resiliency, the distributed EC system supports:
- ✓ In normal situation:
  1. Flow-based resilient communication between end-devices and an EC node via interface diversity

  => SDN allocates the appropriate resources based on the estimated QoE of each flow
  2. Optimal resource allocation among end-device, EC, and BC to meet a diverse QoE requirements such as **latency and blocking rate**.

=> propose an algorithm for the RM to optimally allocate computing (VM) and bandwidth resources.

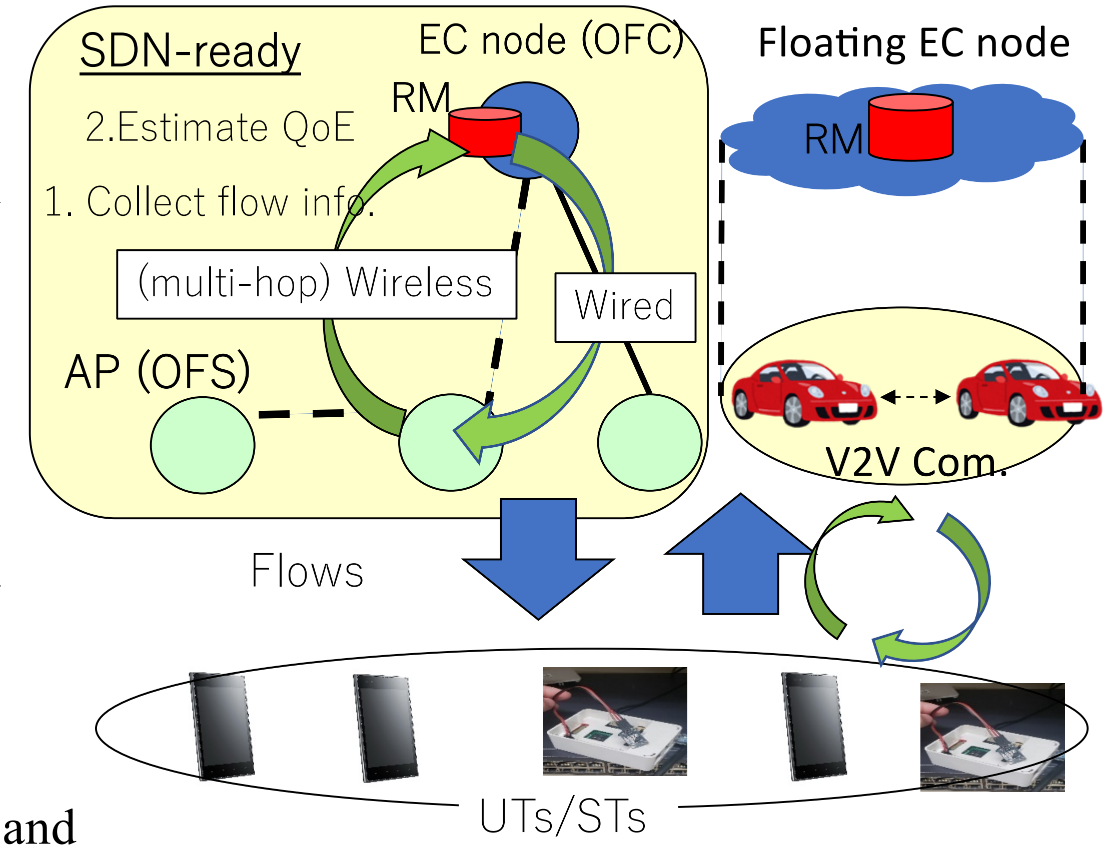

Fig. Concept of End-device networking

- ✓ In resilient situation:
  3. coverage maintenance/extension by introducing spatio-temporal floating EC nodes

Task Members:
Myung Lee (CCNY); Kazuya Tsukamoto, Takeshi Ikenaga, Daiki Nobayashi (Kyutech)

T1-1: Spatio-temporal Floating EC function over vehicular nodes

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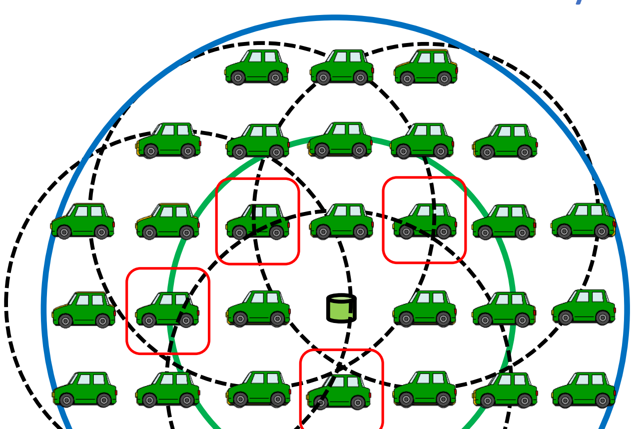
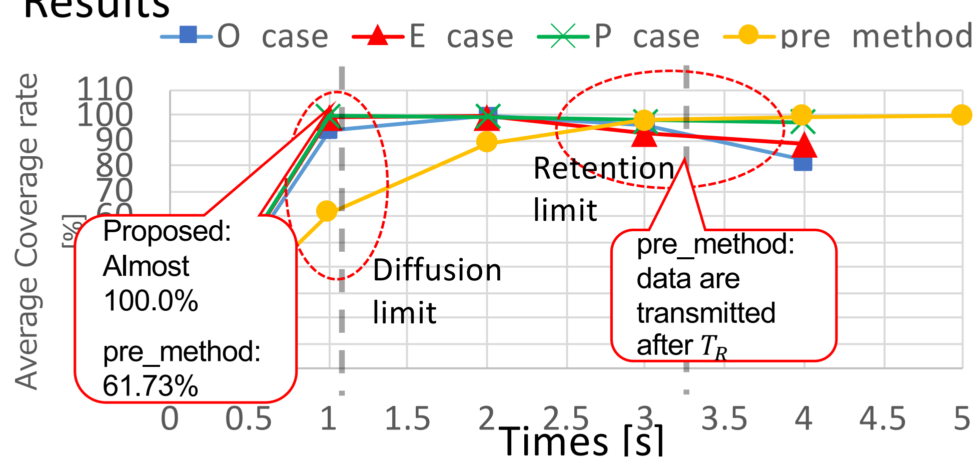
- To achieve floating EC function for providing resiliency of EC node, we propose the data retention system by using vehicular nodes.
  - A vehicular network near the EC node diffuses and retains data (or functions) of the EC node and the Resource Manager (RM).
  - Each retaining data (or functions) have characteristics such as timeliness and validity period => we introduce **diffusion limit and a retention limit**.
  - We propose appropriate data transmission scheme based on data characteristics for the data retention system.
  - As a result, Floating EC provided by the data retention system can provide EC functions to the user when the fixed EC node is down.

An Overview of Data Retention System



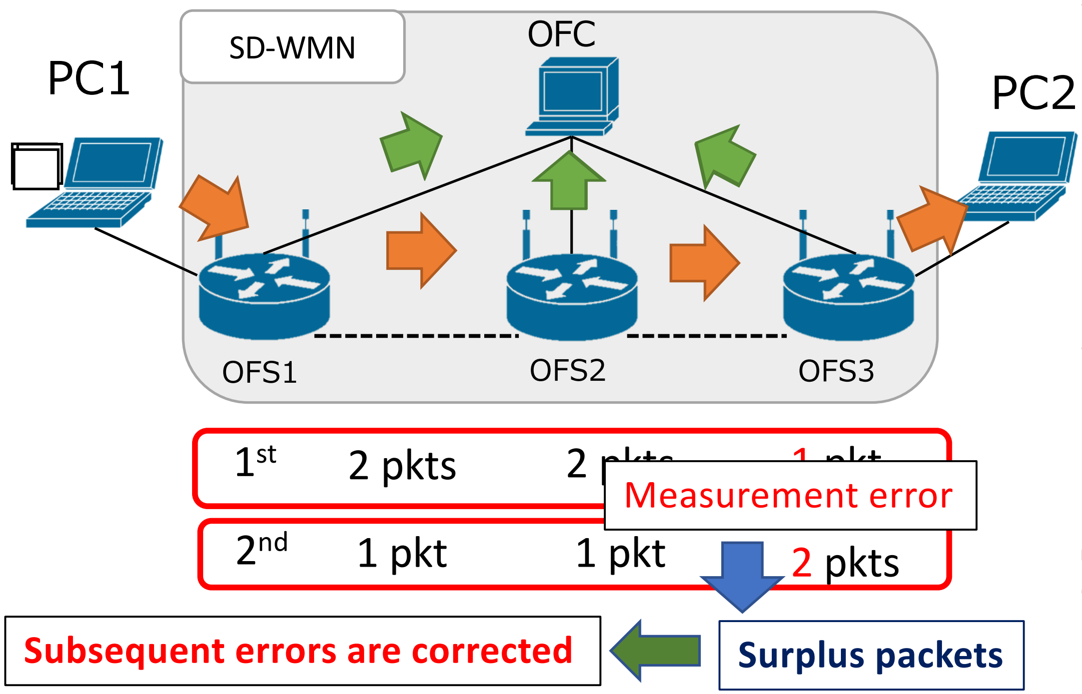
Achieving data retention efficiently based on the data characteristics by transmission control of our proposed scheme

- Experiment
  - We evaluate our proposed scheme using the network simulator Veins (OMNeT++ and SUMO).
  - We evaluate the time required for data spreading.
- Results



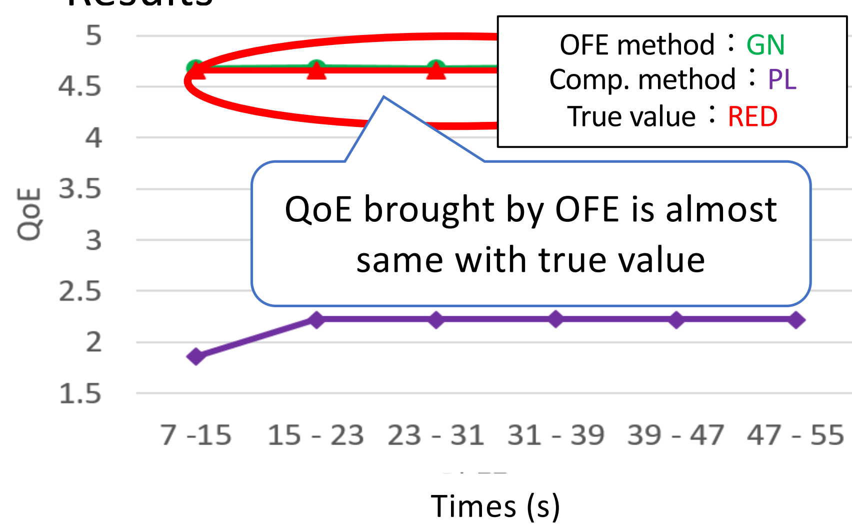
T1-2: Flow-based resilient communication

- We propose OFE (Openflow-based estimation) method
  - We use video streaming app. (G.1071 standard).
  - Measured parameters: (1) Throughput, (2)Packet loss ratio.
  - Video bitrate, Resolution, and frame rate are estimated based on (1) throughput
  - Since measurement error inherently occurs due to the different retrieval timing of FlowStats, packet loss ratio is corrected by using **the accumulated surplus packets**
    - **Surplus packets = (# of pkts of receiver-side) – (# of pkts of sender-side)**



OFE method is effective in case where there is no packet loss in the network !!

- Experiment
  - PC1 sends video flow to PC2 via 1 (2) hop wired/wireless link(s)
  - No packet loss in the network
  - OFC estimates its QoE value based on the OFE method
- Results



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T1-3: Resource Management for Mobile Cloud Computing (MCC) with Edge Cloud

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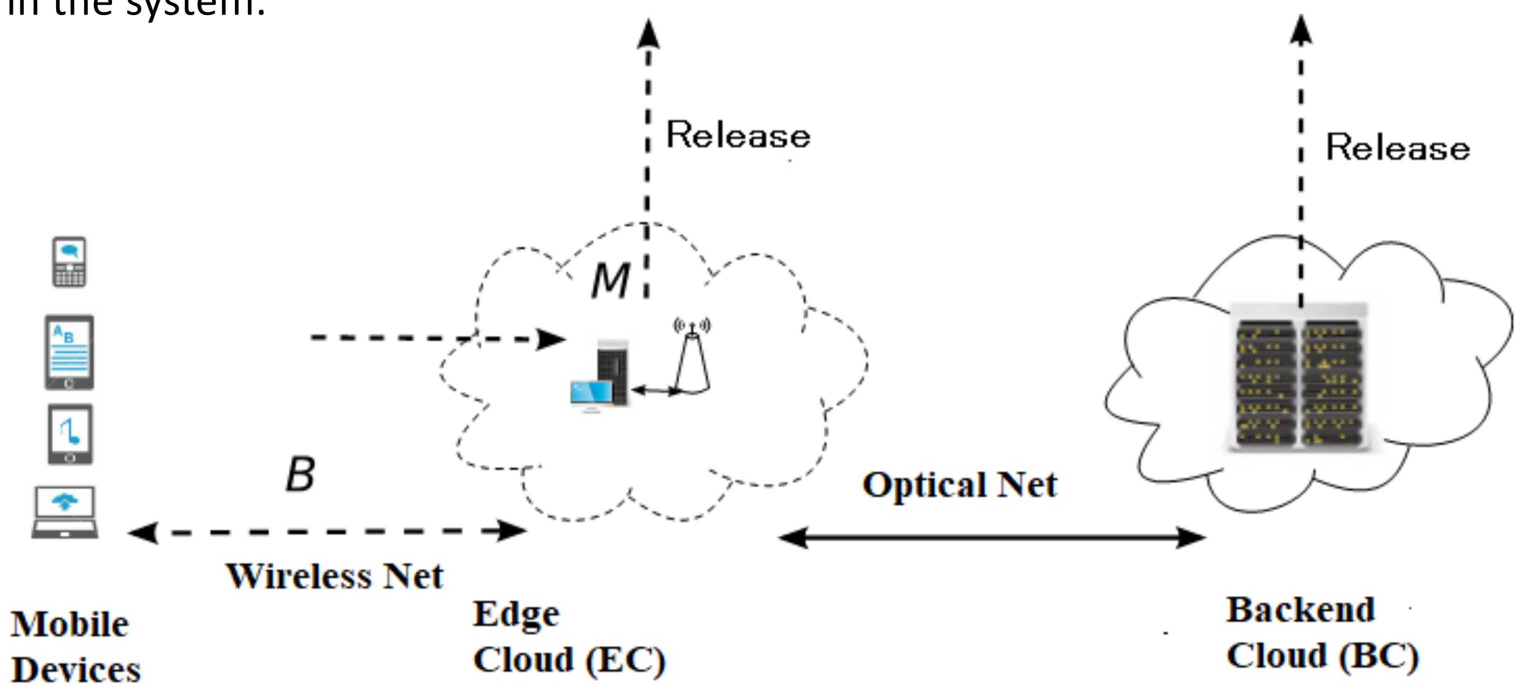
Abstract:

Mobile cloud computing utilizing edge cloud is an emerging technology to improve the quality of mobile services. In order to manage the computational capability of edge cloud and the wireless bandwidth between mobile devices and the edge cloud, we consider the multi-resource allocation problem for the edge cloud environment with resource-intensive and latency-sensitive mobile applications.

The proposed SMDP-based multi-resource allocation (SMDP-MRA) strategy enhances the quality of mobile cloud service, in terms of the system throughput (the number of admitted mobile applications) and the service latency. Through maximizing the long- term reward while meeting the system requirements of the request blocking probability and service time latency, an optimal resource allocation policy is calculated based on SMDP model. From simulation result, it is indicated that the system adaptively adjusts the allocation policy about how much resource to allocate and whether to utilize the distant cloud according to the traffic of mobile service requests and the availability of the resource in the system.



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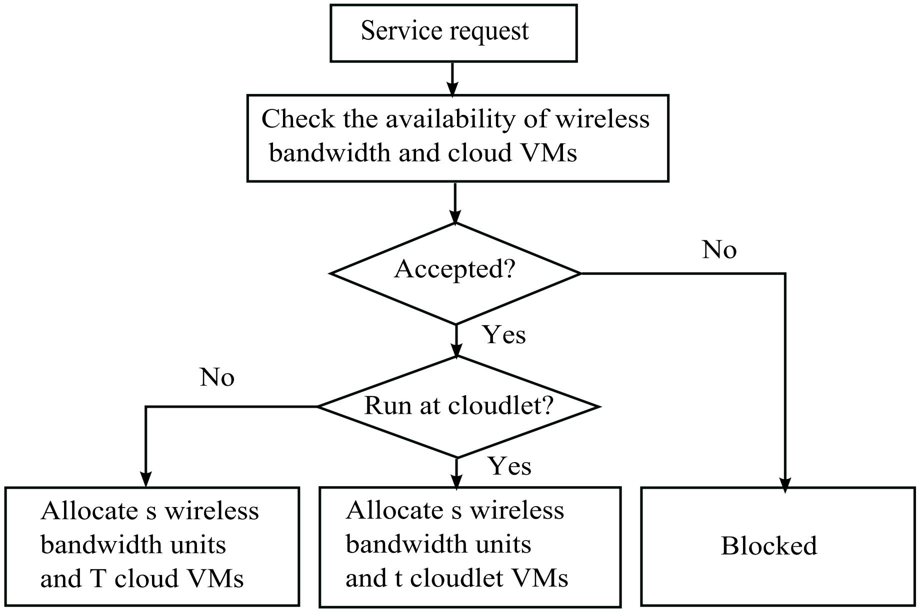
- Problem Statement



- SMDP based Multi-resource Allocation (SMDP-MRA)

State: [#VMs in EC and BC, Wireless BW, current utilization, ***event***]

event {arrival, departure from EC or BC}

Action: {accept by EC or BC, reject}

Reward to consider

Efficiency of EC (low latency);

Resource availability;

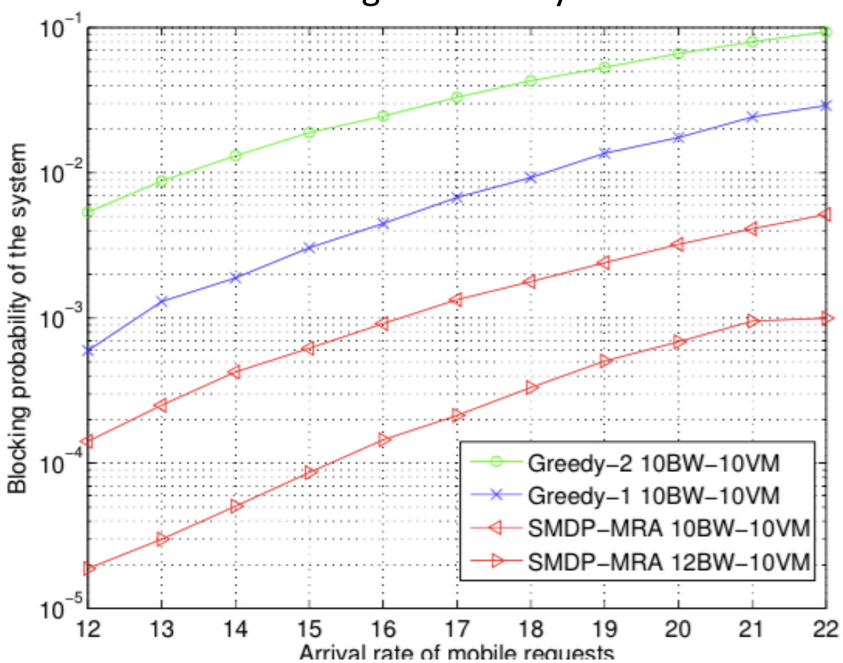
Cost of Service time (C_t)

Computation:

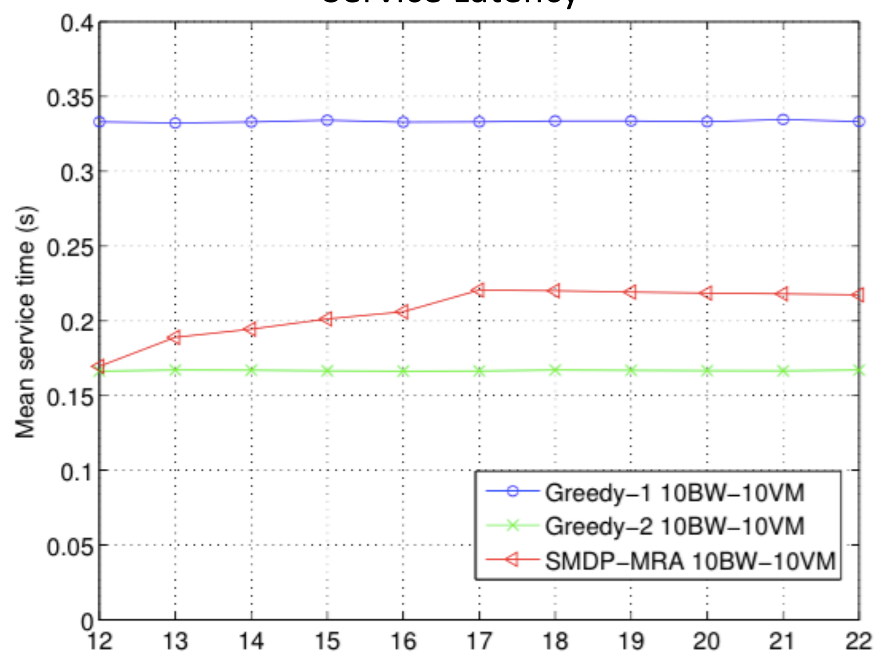
Linear programming

Performance Comparison

Blocking Probability



Service Latency



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T2: Virtualized Adaptable Computing and Networking

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✓Goal: Platform for geographically distributed information sharing and processing with resiliency across edge (EC) and backend clouds (BC)

✓Issues: Resources (computation, storage, communication) => heterogeneous, distributed, and limited; Demands on the resources => diverse and variable in time and space

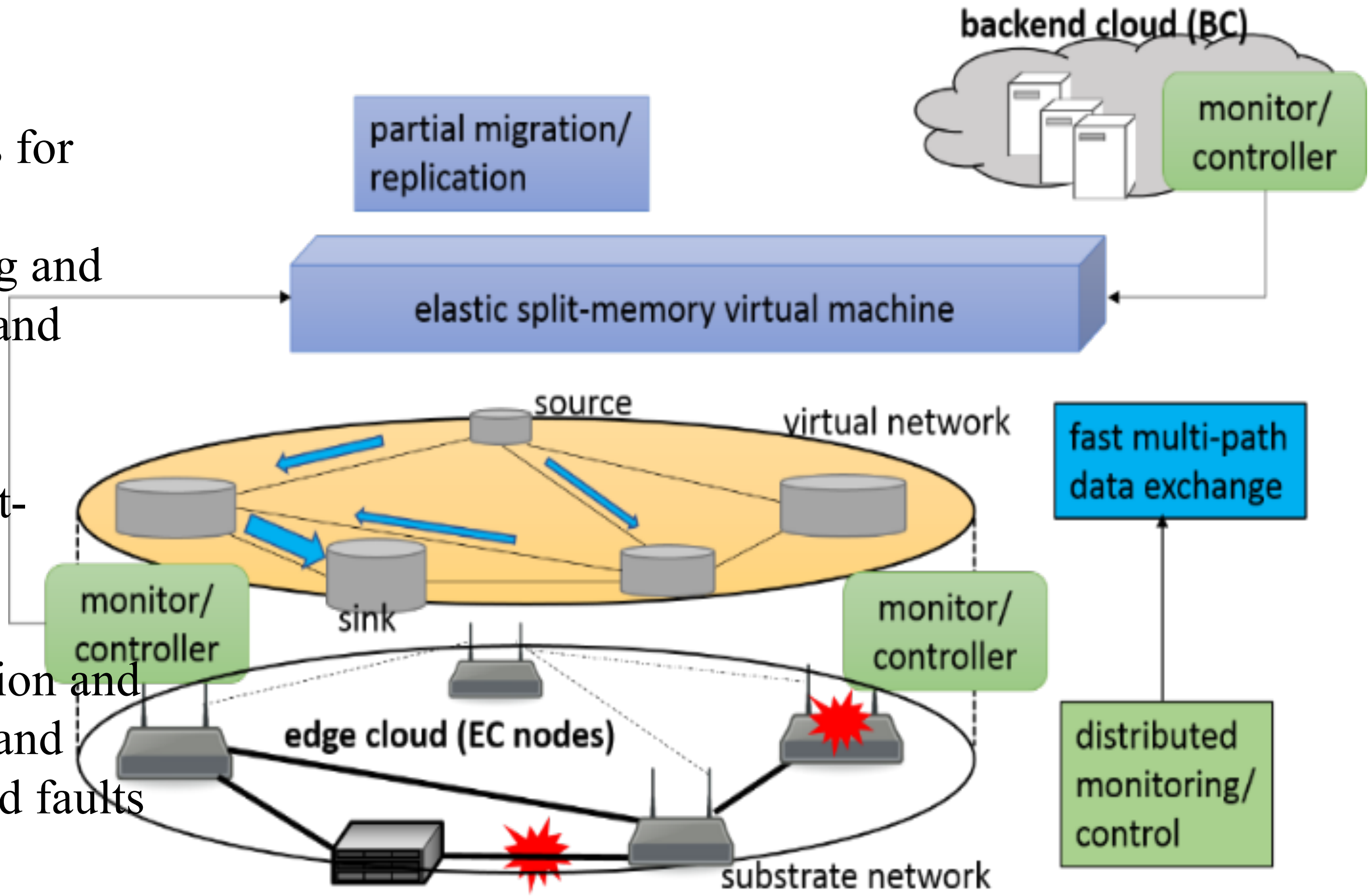
✓Subtasks (T2-1,2,3,4):

(1) Fast multi-path data exchange among EC/BCs for migration and replication

(2) Distributed monitoring and control of links to detect and cope with degradation

(3) Partial migration and replication for elastic split-memory VMs in EC/BCs

(4) Distributed introspection and control of VMs to detect and recover from intrusion and faults



Task Members: Akira Kawaguchi, Abbe Mowshowitz (CCNY); Masato Tsuru, Kenichi Kourai, Kenji Kawahara, Masahiro Shibata (Kyutech)

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T2-1: Fast multi-path data exchange

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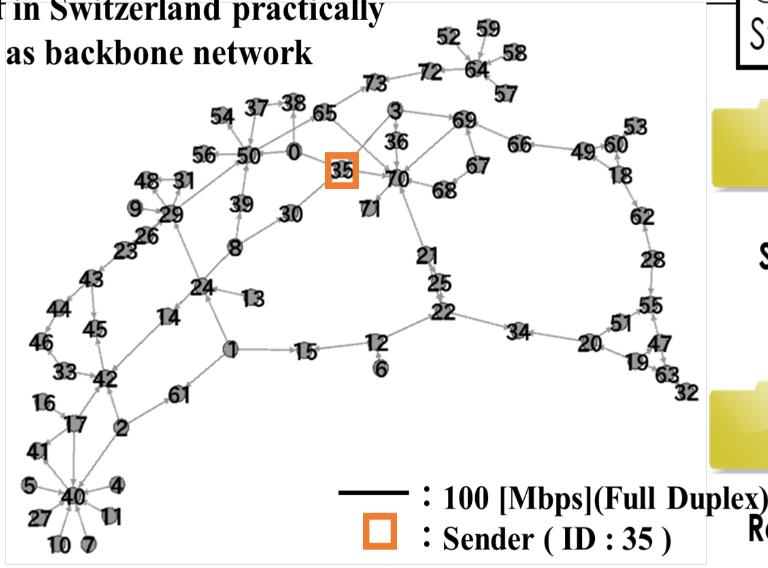
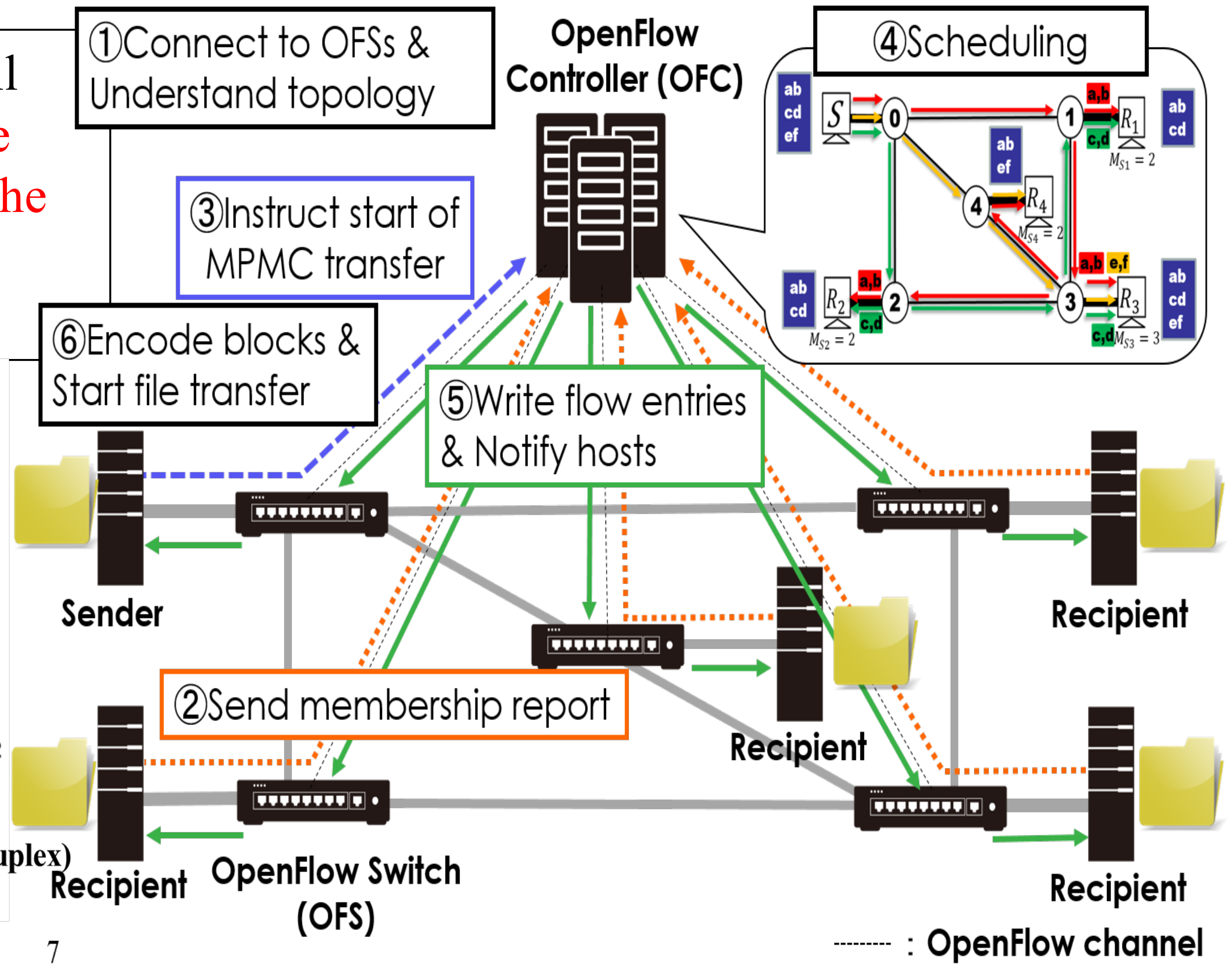
- ✓Delivering a large file to many heterogeneous recipients on full-duplex **OpenFlow** (**OF**) network fast and efficiently; the schedule is computed and directed by the **OFController**.
- ✓Proposal: **Coded-MPMC** = (1) Multipath, multicast, and multiphase delivery of file blocks from the **sender** to each **recipient** over its **max-flow paths** + (2) Reed-Solomon coding of blocks at the sender + (3) Heuristic search of better block allocations on the max-flow paths.
- ✓Minimize the file retrieval completion time (RCT) of each recipient.

Simulation evaluation: In almost all cases, Coded-MPMC can achieve the theoretical lower-bound of RCT (= the file size / its max-flow capacity) for every recipient.

Used in Switzerland practically as backbone network





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T2-2: Distributed monitoring of network links

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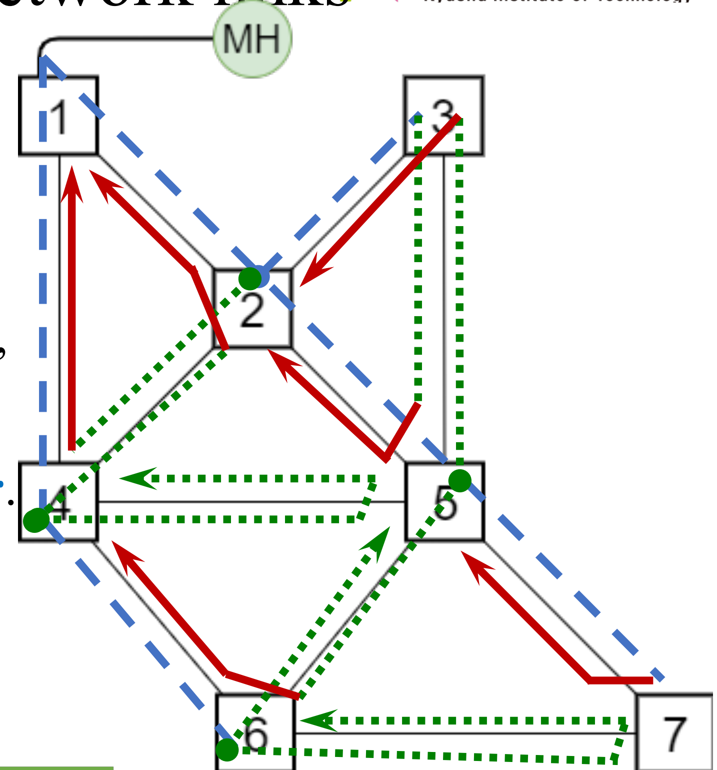
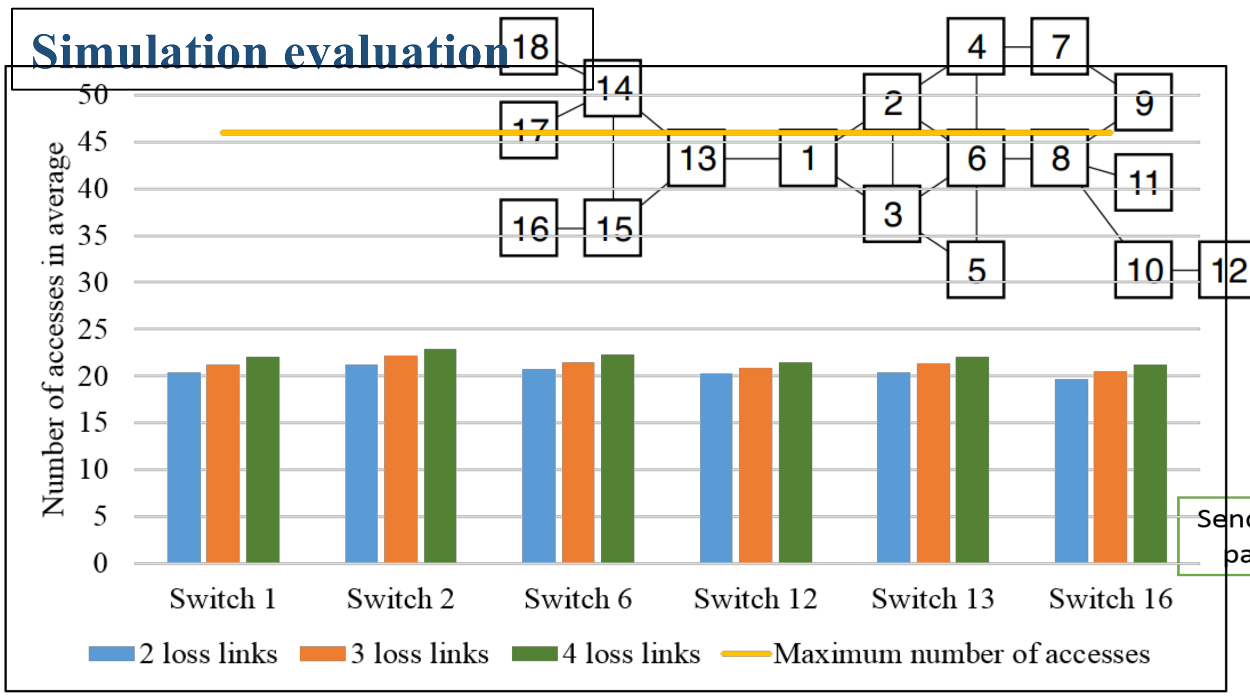
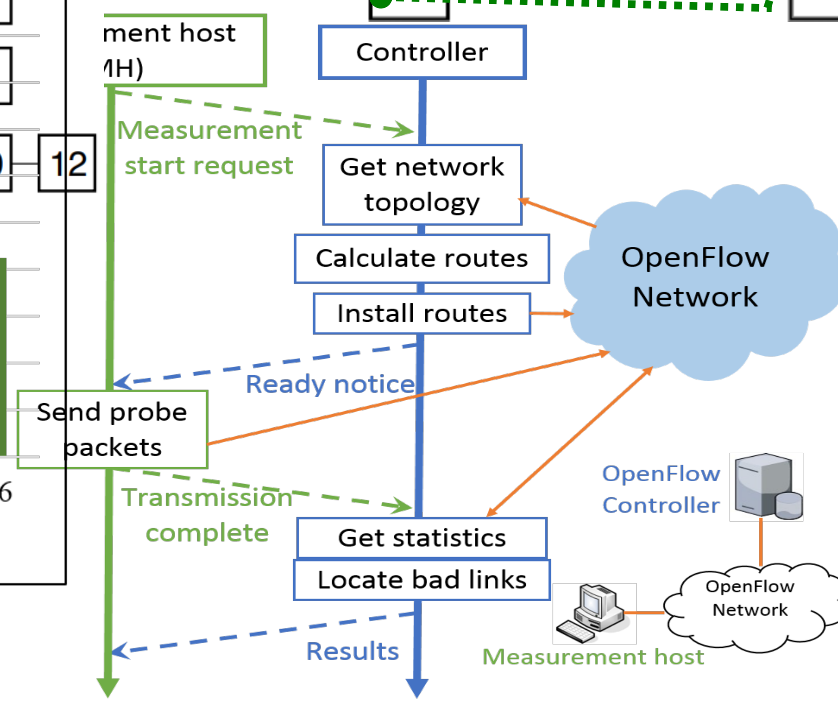


- ✓Monitoring both directions of all links of full-duplex **OpenFlow** (**OF**) network and locating all the high-loss links fast and efficiently.
- ✓Proposal: (1) Active prove packets from **MH** along a multicast route + (2) Passive monitoring of the prove packets' flow stats at each **OFSwitch** + (3) Selective collection of the monitored stats and detection of lossy links by **OFController**.
- ✓Minimizing the number of accesses from OFC to OFSs (for stats collection) until all lossy links are located.

Simulation evaluation





The number of necessary accesses to OFSs is less than half of the number of links regardless of different MH locations

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T2-3:Elastic split-memory VMs in EC nodes and BC

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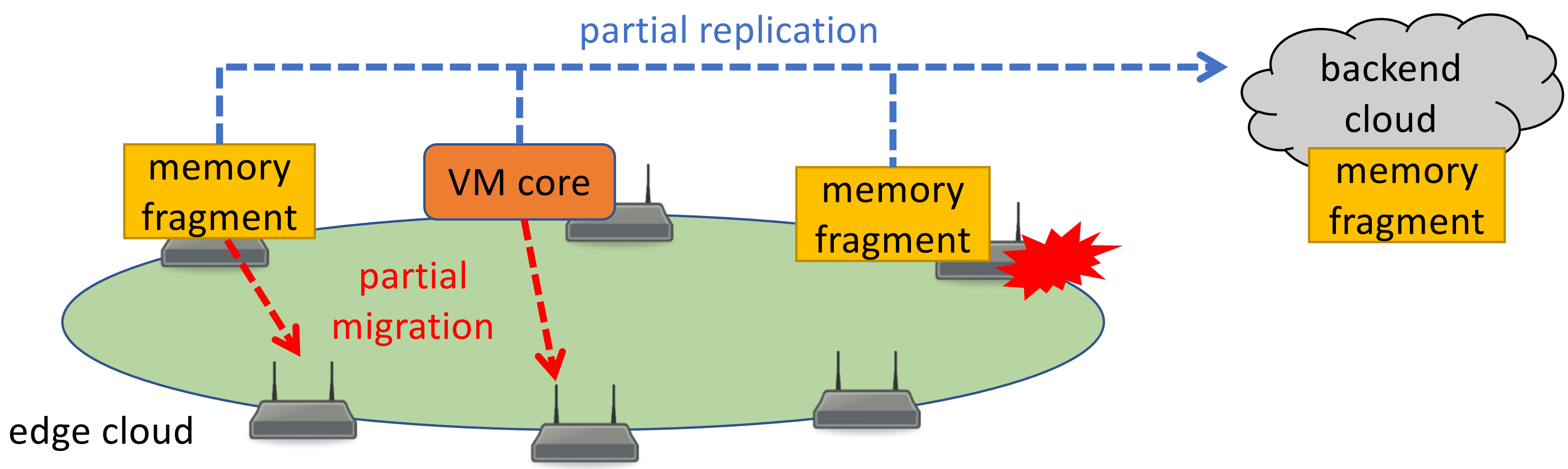
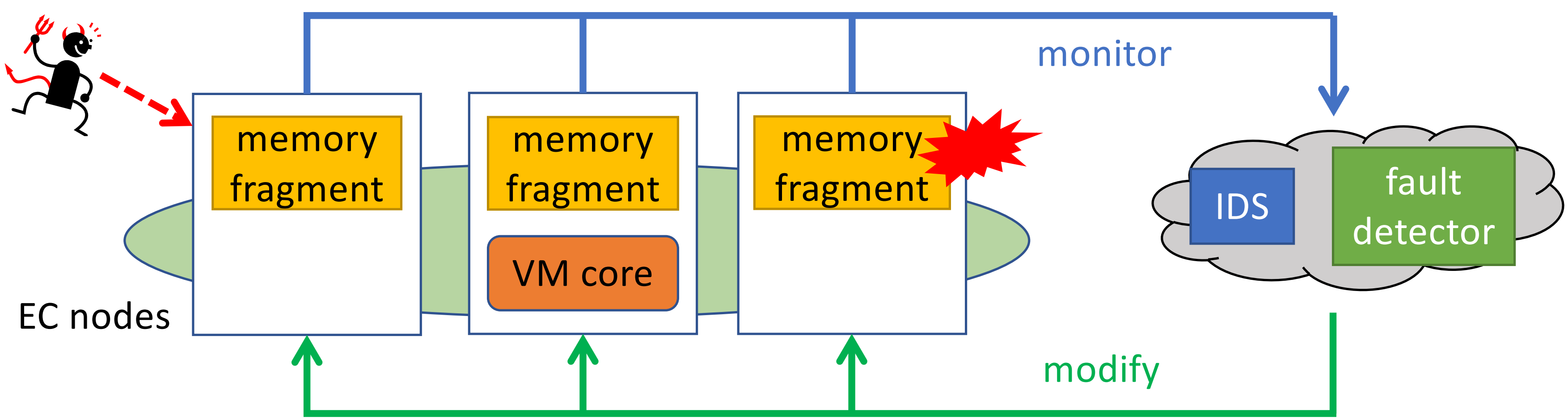
- Develop split-memory VMs efficiently running across EC nodes and BC
  - A split-memory VM consists of a VM core in one node and memory fragments in multiple nodes to use a large amount of memory
  - We achieved efficient split-memory VMs without transferring unused memory data
- Enable partial migration of split-memory VMs
  - Move a VM core and/or memory fragments from overloading nodes to others
  - We achieved two migration methods for substituting a node and merging all nodes
- Perform partial replication of split-memory VMs
  - Replicate a VM core and memory fragments independently against node failures
  - We achieved efficient checkpoint and restore of VMs

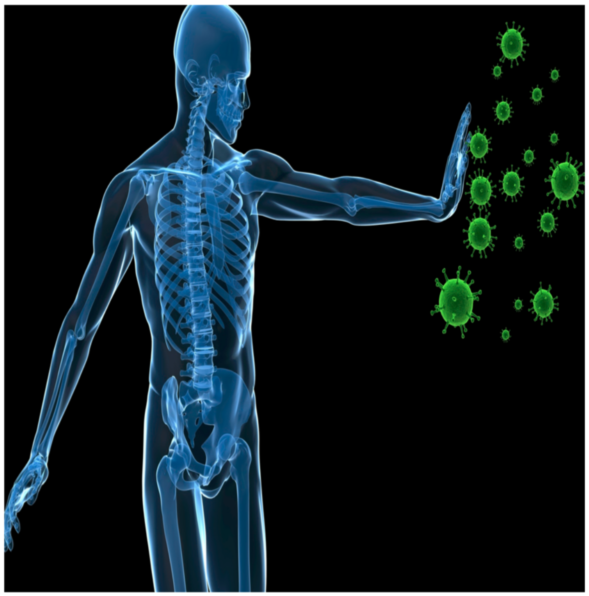


T2-4:Distributed introspection and control for resiliency of split-memory VMs

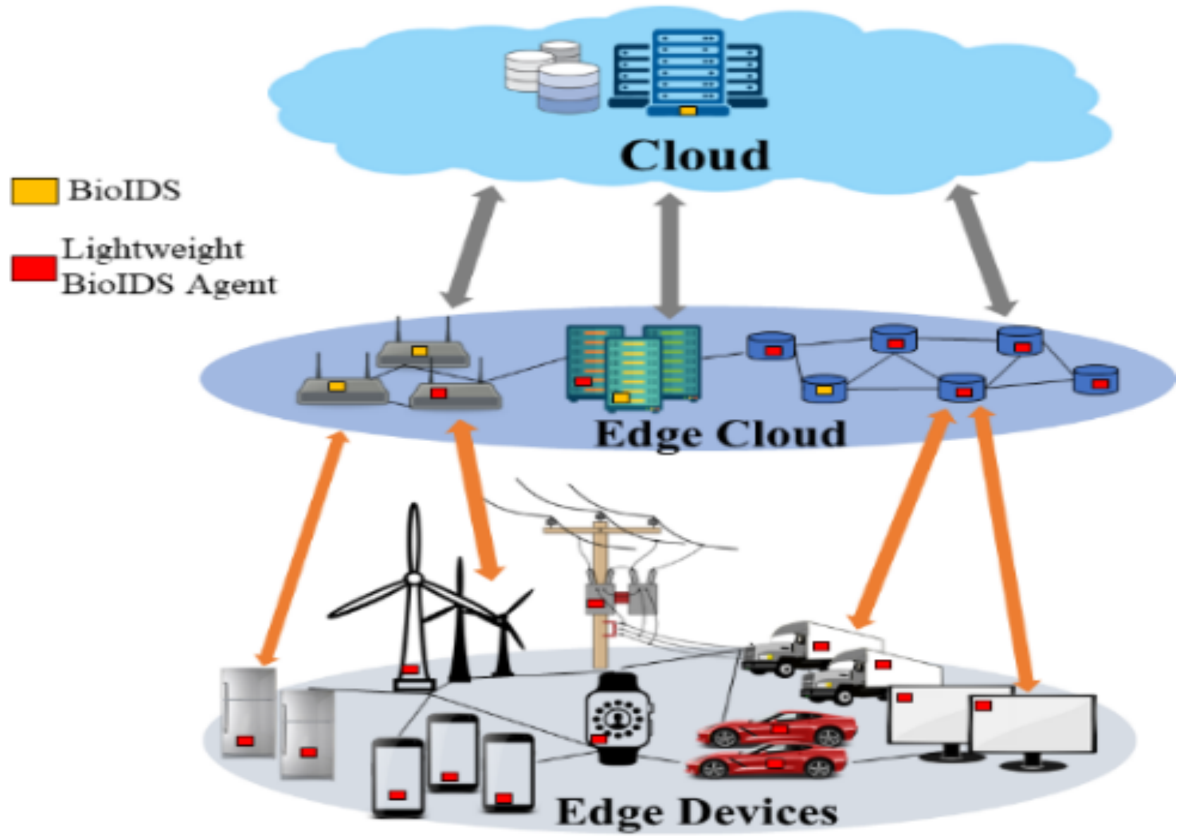
- Develop a distributed introspection mechanism of split-memory VMs
  - Distributed introspection enables monitoring the internal state of a split-memory VM outside the VM
  - Analyze the memory of a split-memory VM across multiple nodes transparently
- Detect intrusion into VMs and faults inside VMs
  - We enabled monitoring OS data in split-memory VMs
  - E.g., CPU/memory utilization, running processes, network usage, etc.
- Recover from intrusion and faults if possible
  - Modify OS data in the VM
  - E.g., changing CPU scheduling, disabling TCP connections, etc.



T3: A Bio-Inspired Intrusion Detection System (BIIDS) for Protecting IoT Devices



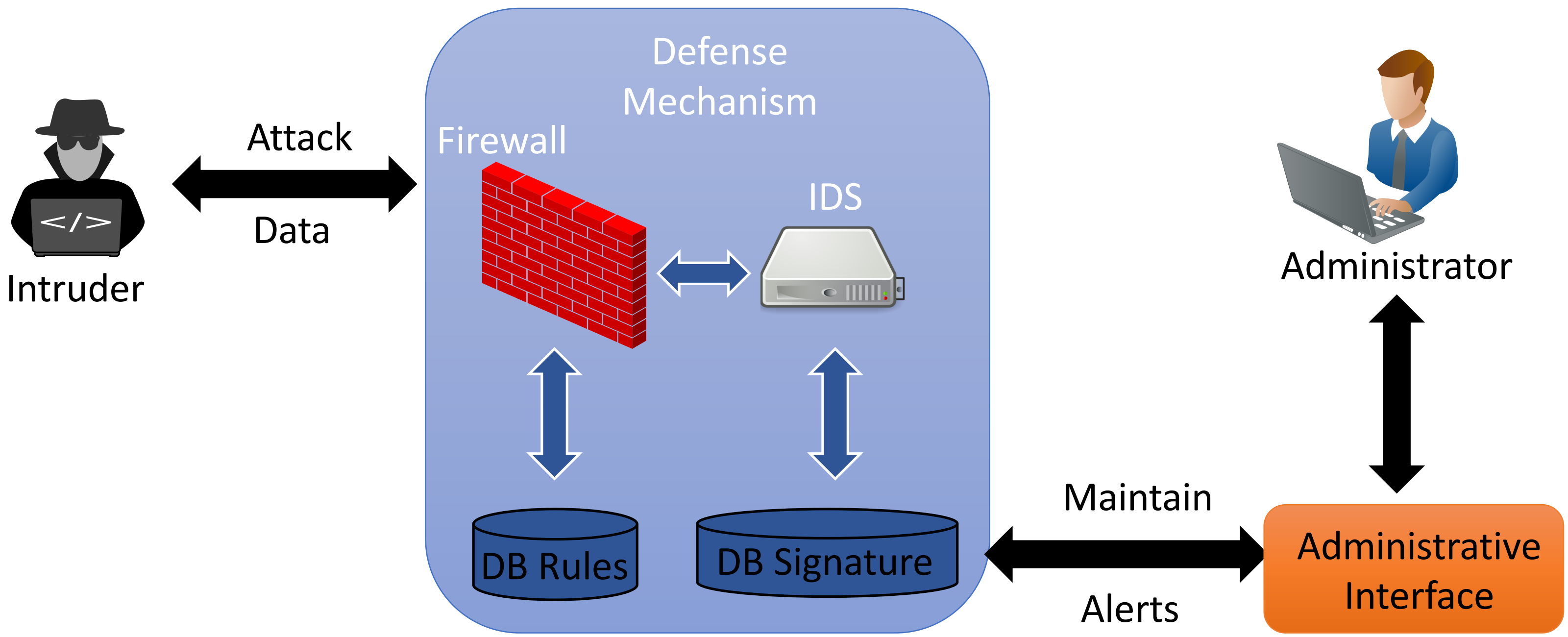
Artificial Immune System (AIS) Approach.



Architecture for IoT device/network security using BioIDS and lightweight agents.

Intrusion detection system

STANDART MODEL



Current Solutions to the Security Challenges of Internetworking

Firewall

- ❑ **Firewalls, IPSEC, VPN/tunneling**
- ❑ **Security Policies**
- ❑ **Intrusion Detection Systems (IDSs)**
  - **Signature-Based IDS – Match all incoming traffic with signatures stored in a database. If a traffic matches, then its an attack (SNORT, BRO IDS).**
  - **Anomaly-Based IDS – Learn accepted network behavior, then use this learned behavior to identify future behaviors that do not conform to this baseline.**

Artificial Immune System Approach

- Based on human immune system (HIS)
- Fully distributed and hence no central controller
- Only informs the agents of actual intrusions
- Uses genetic algorithm (GA) based on negative selection algorithm (NSA)

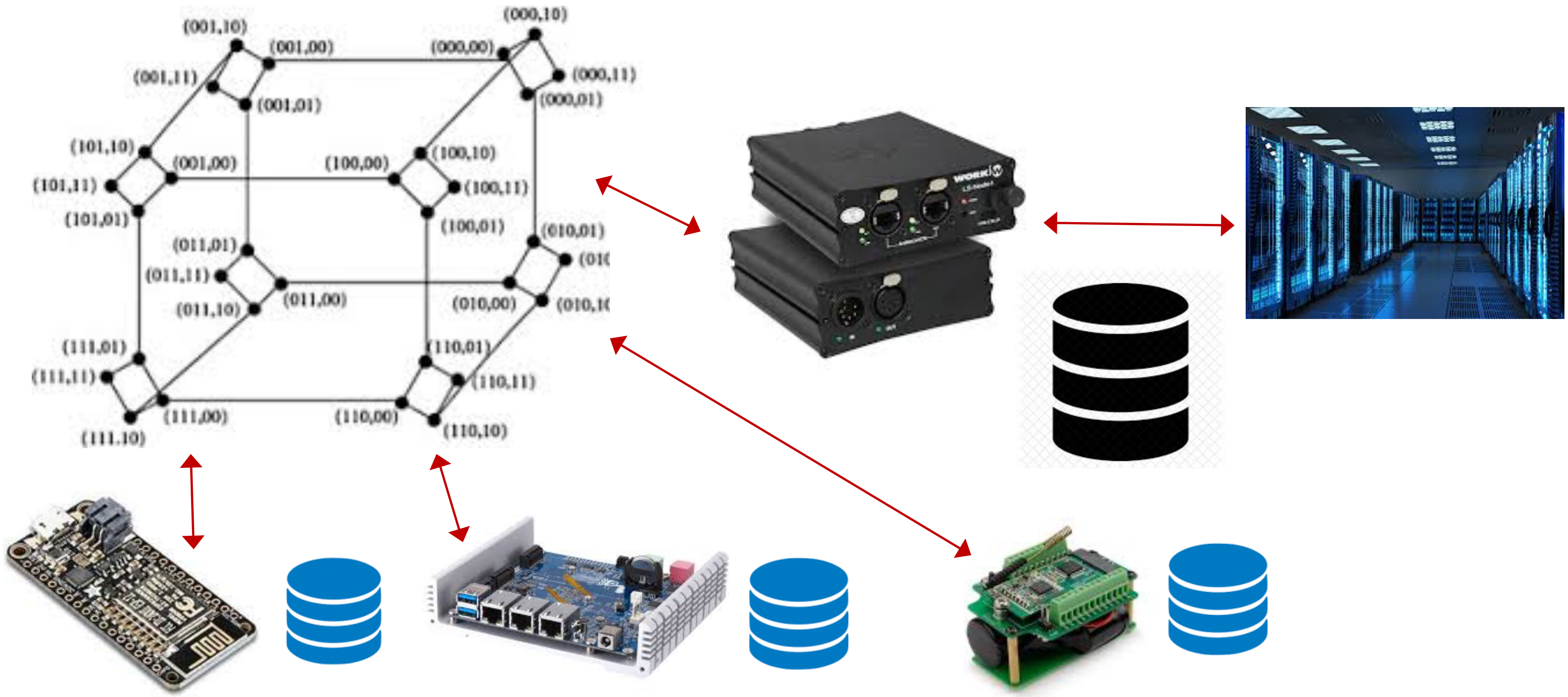
Advantages of the Immune System Approach

- Based on the Human Immune System.
- Distributed and Effective in Large Networks.
- Detects Zero-day attacks and Insider Threats.

T4: Embedded hypercube database as subsystem in SDN

ENGINEERED NETWORK

Embedded Hypercube Network   Intelligent & Decision Systems   Secure Cloud Storage

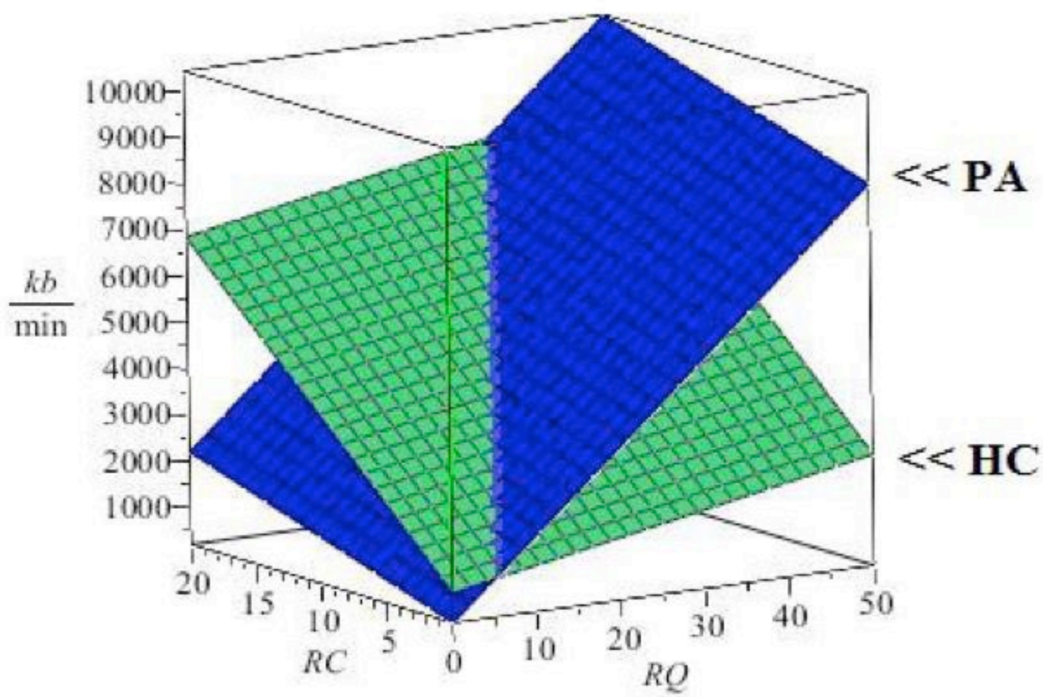


Edge Device Group A   Edge Device Group B   Edge Device Group C

Task4 Investigators: Abbe Mowshowitz, Akira Kawaguchi (CCNY); Masato Tsuru, Shibata Masahiro (Kyutech)

RESEARCH APPROACH AND RESULTS

- **Challenges**: 1) maximize use of edge nodes, 2) minimize message traffic, 3) support efficient data querying
- **Approach:** optimize distributed data queries based on network distance between edge nodes



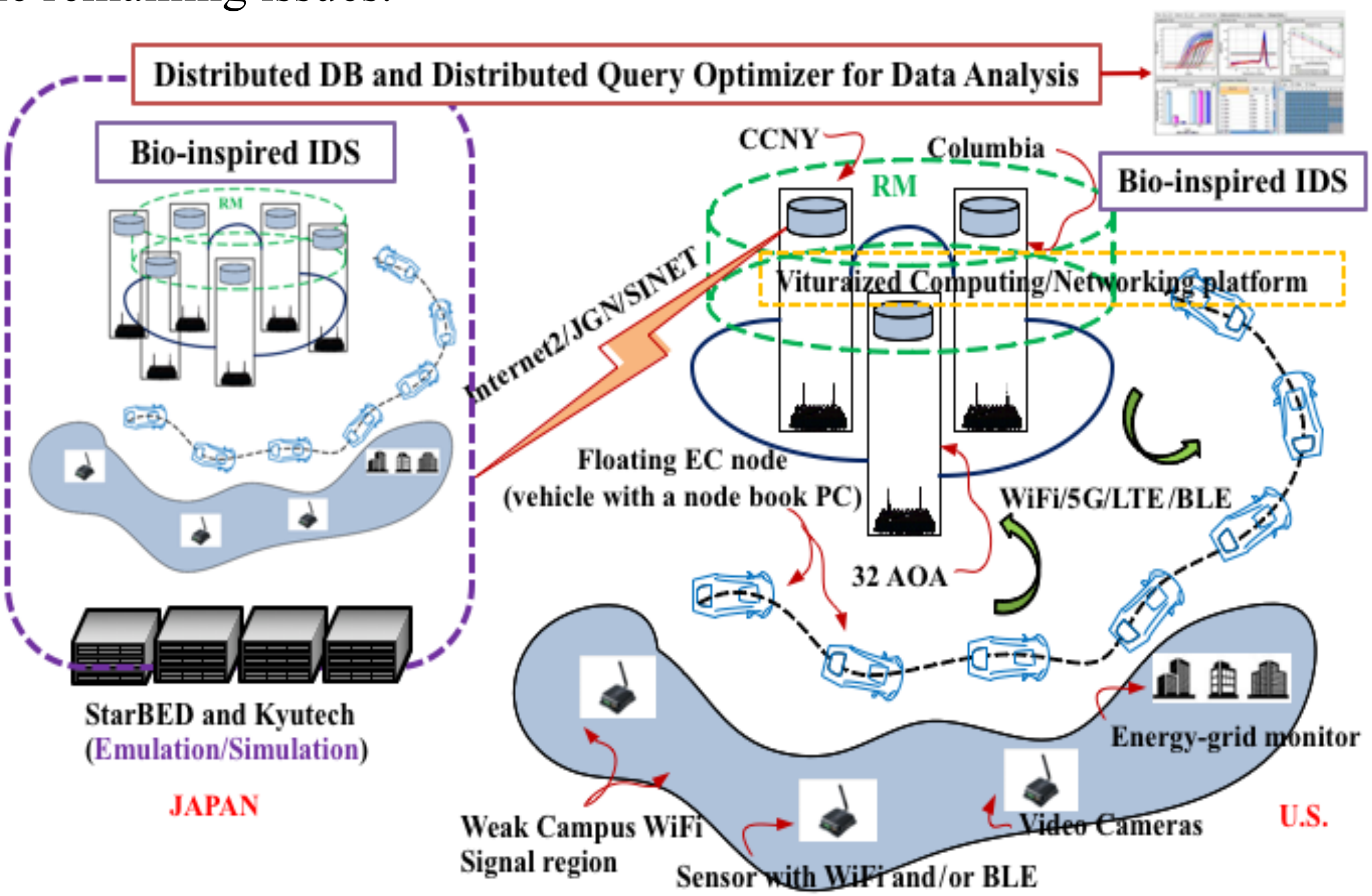
PA: Preferential Attachment
HC: Hypercube
RQ: Rate of Query
RC: Rate of Change in network

Hypercube advantage*:*
High RQ, Low RC

Testbed Experiments

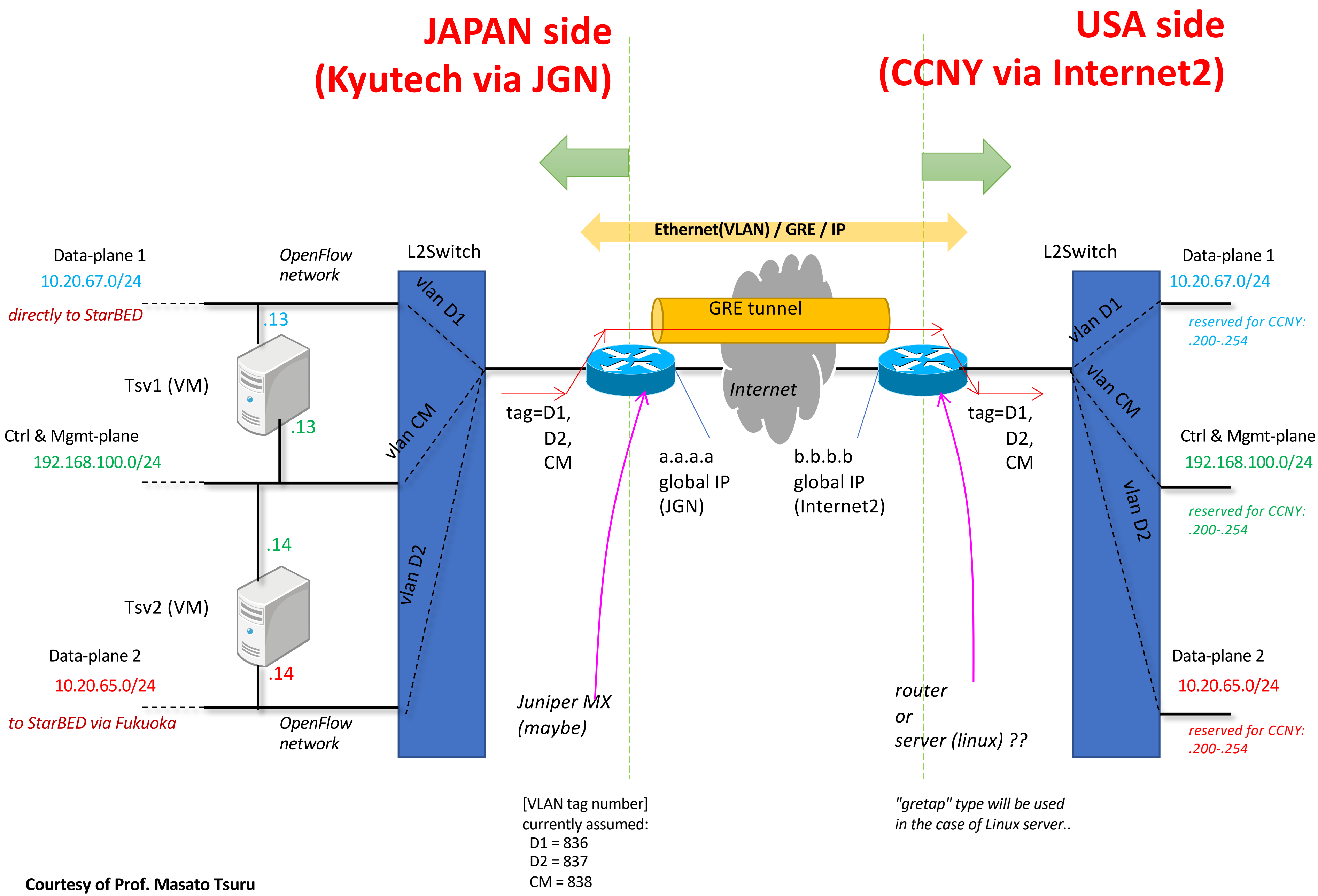
✓Integrated Large-Scale Real and Emulation Experimental Testbed across a real city-scale testbed in US (COSMOS) and a large-scale emulation/simulation testbed in JP (StarBED) to realize a global edge-cloud networking testbed with diversity and programmability.

✓Use-case oriented application experiments to evaluate the feasibility and effectiveness, and to clarify the remaining issues.



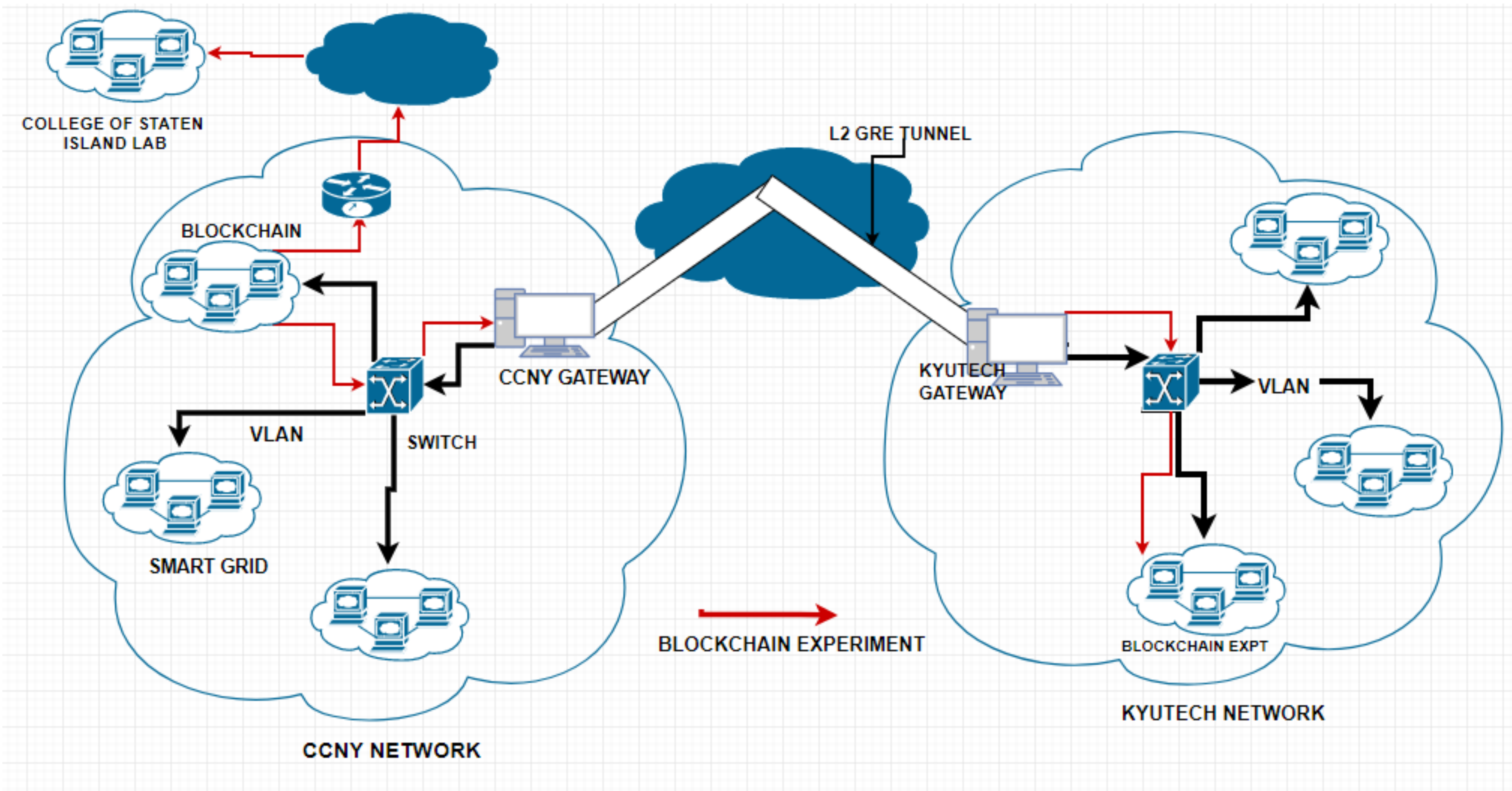
Task Members: Myung Lee and all other members in CCNY; Masato Tsuru and all other members in Kyutech

Network Setup



Courtesy of Prof. Masato Tsuru

CCNY-Kyutech Blockchain Collaboration



COSMOS Testbed

- CCNY is the testbed partner of NSF COSMOS (*Cloud Enhanced Open Software Defined Mobile Wireless Testbed for City-Scale Deployment)*
  - Currently, both Columbia and CCNY are in the process of installing antennas and fiber network in each campus and interconnect between the two campuses, thus providing for 5G testbed

- Can Kyutech-CCNY testbed be connected to COSMOS testbed?

Thank You