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

October 26, 2018

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

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 (Partners):

- **Takeshi Ikenaga**
- **Kenji Kawahara**
- **Kenichi Kourai**
- **Daiki Nobayashi**
- **Masahiro Shibata**
- **Kazuya Tsukamoto**
- **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)**

Intellectual Merit

- **The traditional centralized architecture cannot accommodate such user demands due to massive load on the core network and long latency.**

- **Therefore new architectures, which bring network functions and contents such as computing and communications to the edge of the network, are proposed.**

- **This work will result in collaborative and fundamental research that will advance the knowledge and know-how in the field.**

Broader Impact

- **The proposed work is essential for resilient edge cloud/networking to make the human society smarter and safer.**

- **The proposed work will result in numerous high-quality publications that will maximize utility and reusability of our approaches.**

- **Students will be selected from a diverse pool, including internationally, and one aim of the project will be to increase diversity and the representation of women and minority in Engineering.**

- **This project will enhance scientific collaboration between the two countries.**

Communications and Regular Meetings

- **Monthly Meeting with Video Conference (two meetings already; 9/ 20/2018 and 10/18/2018**
- **Setup URL at Kyutech for video conferencing**
- **Created a mail list for all team members**

Planned Visits

- **This Fall semester (Early December): Visit by Kyutech to CCNY**
- **Spring semester: Kyutech visit to CCNY (March 2019)**
  CCNY visit to Kyutech (Early Summer 2019)
- **(Pre-award meeting was held in Japan in 6/18/2018)**

Task Coordinators

- **Each task (4+1) is assigned two coordinators; one from Kyutech and one from CCNY**

Pre-Award Meeting, June 18, 2018, Kyutech Institute-Japan

Left to Right: (KYUTECH-Japan) Professors Kenji Kawahara, Kenichi Kourai, Kazuya Tsukamoto, Eiji Hayashi, Masato Tsuru
(CCNY-USA) Abbe Mowshowitz, Tarek Saadawi, Myung Lee, Akira Kawaguchi
Not Present: Professors Takeshi Ikenaga, Daiki Nobayashi, Masahiro Shibata

NETS: JUNO2: RESILIENT EDGE CLOUD DESIGNED NETWORK

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** **Masato Tsuru (Kuytech)** **Myung Lee (CCNY)** and all team members

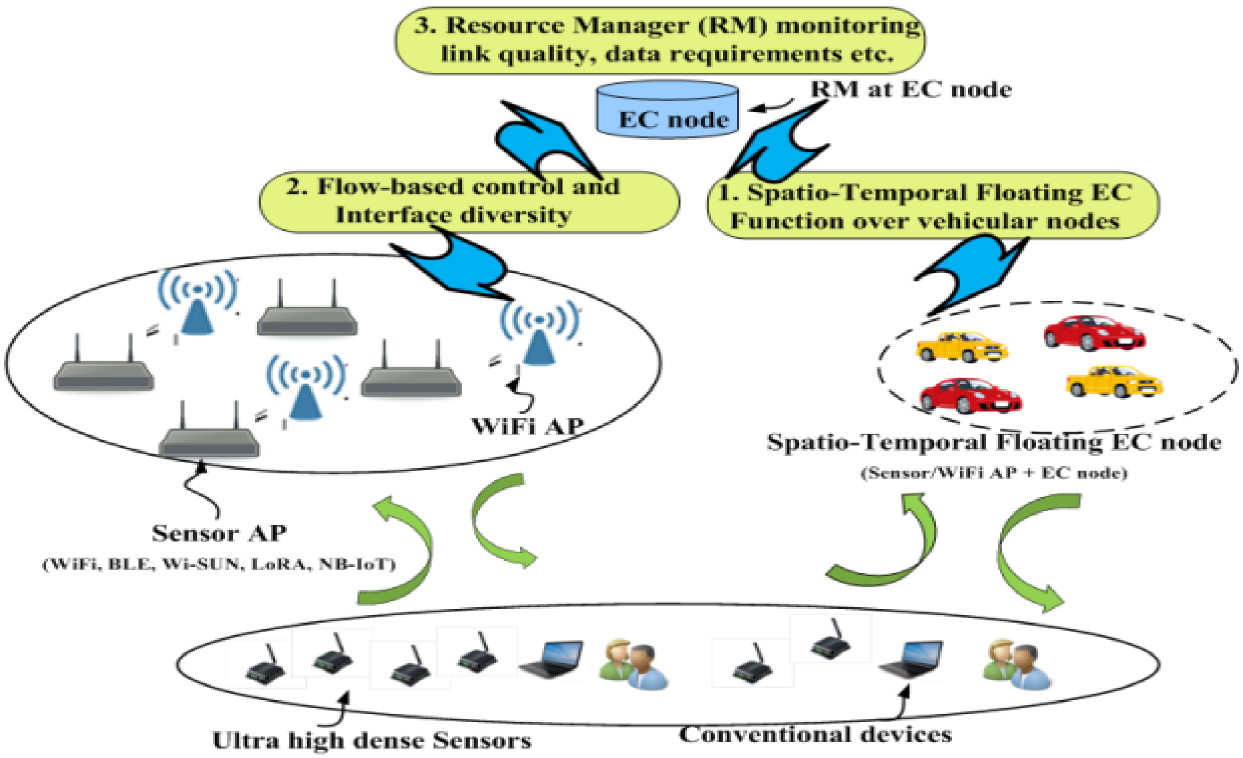
  Test scenarios: 1) Safety by facial recognition.

  2) Managing a distributed electric power grid based on designed hypercube network

The City College of New York

Kyutech Kyushu Institute of Technology

T1: Resilient Resource Access for Massive End Devices



Concept of End-device networking

General Plan of Work

Step 1: introduce vehicular EC node to extend service coverage and to serve as temporal EC node, and apply the SDN function to floating EC node to allocate proper wireless resources to each of data flows. Also propose an algorithm for the RM to optimally allocate computing (VM) and bandwidth resources.

Step 2: extend the algorithms proposed in Step1 to consider the dynamic change in not only link quality but also communication traffic, and implements these methods as subsystems in the SDN environment.

Step 3: develop a structure for efficient integration of SDN control and RM decision. Furthermore, develop a failover scheme in which the running VMs can be migrated to nearby available EC nodes, to support reliable services.

Impact

✓ The distributed resilient EC system as a network of geographically distributed EC nodes, brokering between end-devices and Backend Cloud (BC) server offers the advantages for:

- Fulfiling a diverse QoS requirement
- Resiliency of computing and connectivity
- Scalability to support massive number of end devices

✓ The distributed resilient EC system supports (1) coverage extension by introducing spatio-temporal floating EC nodes, (2) flow-based resilient communication between end-devices and an EC node via interface diversity, and (3) optimal resource allocation among end-device, EC, and BC to meet a diverse QoS requirements such as **latency and blocking rate**.

Milestones:

Year 1: Design and analysis of Resource Management Framework, which will be undertaken in the consideration of traffic demand and QoS, including a flow control algorithms.

Year 2: Performance evaluation and Software Development Analytical and simulation study for resource management for various EC scenarios.

Year3: Results of steps 1 and 2 will be ported to the integrated testbed.

Task Members:

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

T2: VIRTUALIZED ADAPTABLE COMPUTING and NETWORKING

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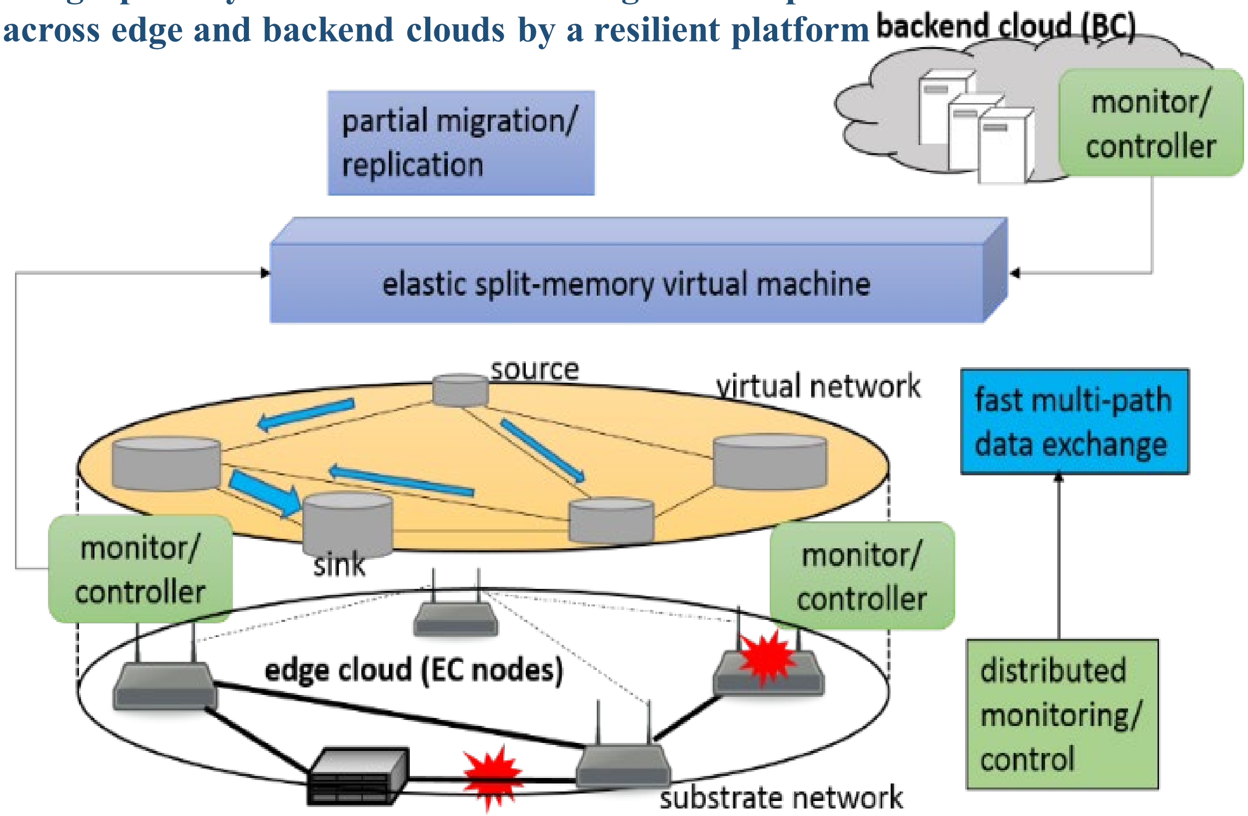
Geographically distributed data sharing and computation across edge and backend clouds by a resilient platform



General Plan of Work

Step 1: Develop the following OpenFlow-based network functions and Virtual Machine (VM)-based computation functions for adaptability.
(T2-1) Fast multi-path data exchange among EC/BCs for migration and replication
(T2-2) Distributed monitoring and control of links to detect and cope with degradation
(T2-3) Elastic split-memory VMs in EC/BCs for partial migration and replication
(T2-4) Distributed introspection and control of VMs to detect and cope with degradation

Step 2: Integrate the network functions and VM functions developed in Step 1. These functions are used in a distributed data sharing and computation platform with interfaces to other tasks (T1, T3, and T4) to realize effective interplays of those tasks.

Impact

✓ Distributed data sharing and computation can provide
 * Shorter response times by access and processing proximity,
 * Location-dependent services in a more efficient and robust manner.

✓ The proposed virtualized adaptive computing and networking platform is resilient to diverse and dynamically varying resources and demands for computation, storage, and communications, based on
 * Intrinsic adaptability **of Virtual Machine (VM) and OpenFlow-based network**,
 * Functions for **fast migration and replication** (T2-1, T2-3),
 * Functions for **fast degradation detection and recovery** (T2-2, T2-4).

Milestones:

Year 1: Design and develop the key functions of each subtask in parallel.
Year 2: Develop and test the platform to combine the VMs and networks including the basic operation part and the management part in a lab environment.
Year 3: Evaluate the integration of Task 2 on the testbed experiments with some application scenarios.

Task Members:

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

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

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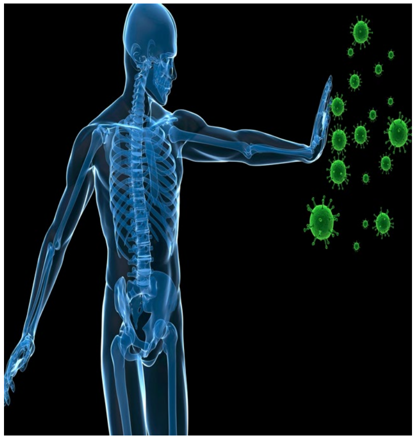
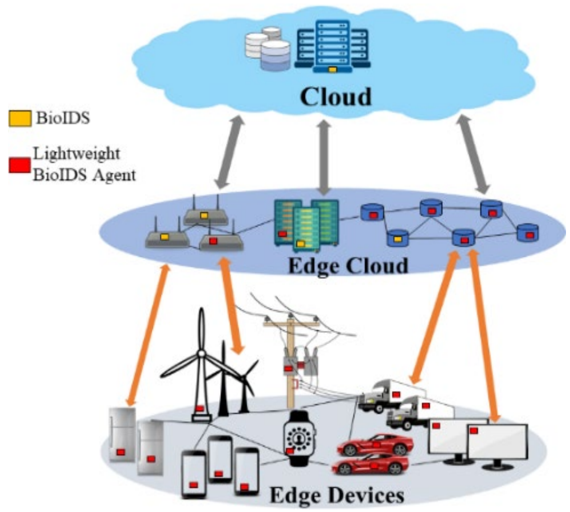


Artifcial Immune System (AIS) Approach.



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

General Plan of Work

Step 1: basic features are generated or extracted from ingress network traffic to the internal network where protected servers reside

Step 2: Signals that represent abnormal activities (danger signals) and normal activities (safe signals) are generated using the features extracted in Step 1.

Step 3: In the training phase, the NSA instances that make up the NSA module are trained using the two signals generated in Step 2.
The decisions made by the constituent NSA/DCA modules are weighted (using the weights determined during the training phase) and used by the decision-making module to distinguish DoS attacks from legitimate traffic.

Impact

- ✓ A tool which makes use of the algorithms that exist in an area under artificial intelligence known as artificial immune system (AIS) to provide *unified infrastructure for insider/outsider threat detection* in:
  - Smart Grids
  - Enterprise Networks
  - Connected Autonomous Vehicles
  - Mobile Adhoc Networks
- ✓ For its insider threat prediction capability, it supports Quick Search for any specific user based on name and other diverse search criteria or options.

Milestones:

- ✓ Year 1: detailed analyses of IoT device/network attack surfaces

Year 2: developing a lightweight software agent that will run on IoT devices/edge-cloud nodes especially on those that have constraints on memory and processing capability.

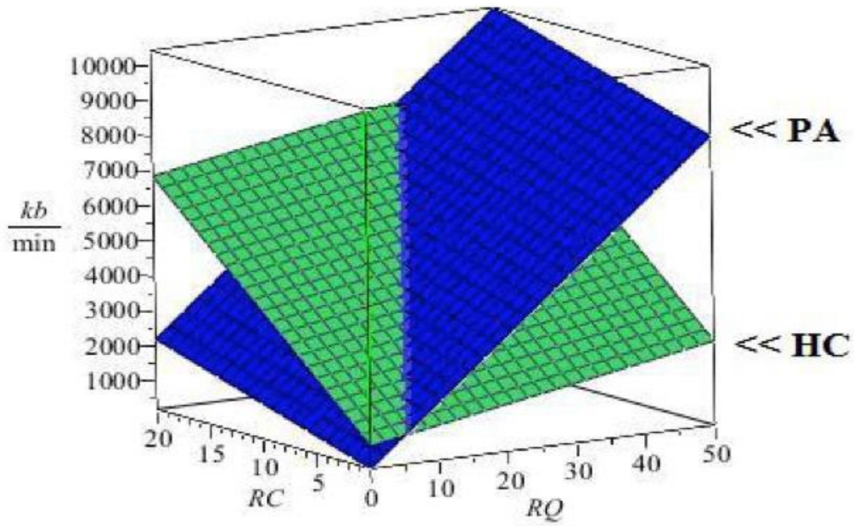
Year 3: perform penetration testing in real-time against the IoT devices or cloud/edge-cloud nodes using the information and vulnerability analysis results obtained

Task Members:

Tarek Saadawi (CCNY), Kenichi Kourai (Kyutech)

T4: DISTRIBUTED DATABASE USING HYPERCUBE

Engineered Hypercube vs. Random Network



General Plan of Work

Step 1: Create a hypercube version of the open source GaianDB and populate it with equipment data from the use case connected with an electric utility. The engineered hypercube (colored green in the diagram) has a clear advantage when the rate of change in the network structure is relatively low and the query rate is relatively high.

Step 2: Implement the database developed in Step 1 as a subsystem in a software defined network environment.

Step 3: Develop strategies for optimal querying in the hypercube system. In particular, determine feasibility of designating network nodes as temporary processing centers for query operations such as join and semijoin.

Impact

- ✓ An engineered hypercube as an overlay network in a dynamic, distributed database is an efficient system for querying under certain conditions, and offers the advantage of substantial reductions in network traffic and thus lowers bandwidth utilization.
- ✓ Implementation in a software defined network environment will make the engineered hypercube into an efficient and practical distributed database tool.

Milestones:

Year 1: Design and development a distributed query optimizer. The target application will be designed to gather data for real-time analysis and monitoring.
Year 2: Hypercube database and query optimizer will be integrated into subsystem by means of software-defined networking.
Step 3:Results of steps 1 and 2 will be ported to the integrated testbed with other subsystems.

Task Members:

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

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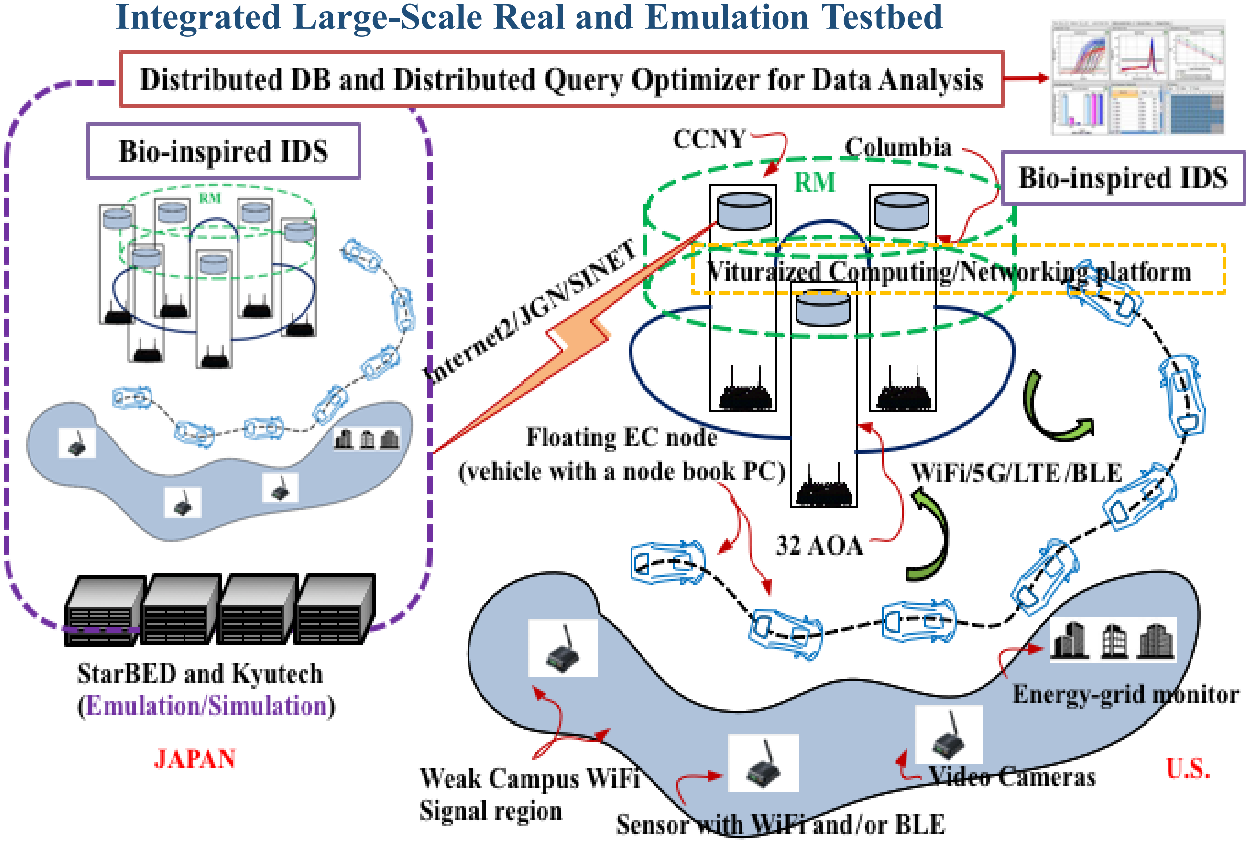
Kyutech
Kyushu Institute of Technology

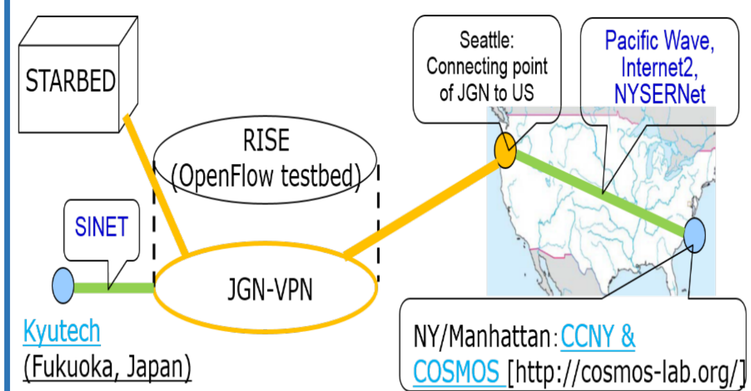
TESTBED EXPERIMENTS

Integrated Large-Scale Real and Emulation Testbed



General Plan of Work

Step 1: Build the testbed environments, i.e., networking and computing resources, with int'l collaborations.
Step 2: In parallel, select use-case applications (e.g., Distributed electric-power grid, Smart-city person identity by facial recognition). Then design, develop, and test the experimental scenarios.
Step 3: Conduct the experimental evaluations on the integrated testbed across US and JP.



Impact

- ✓ An integration across a real city-scale testbed in US (**COSMOS**: Cloud Enhanced Open Software Defined Mobile Wireless Testbed for City-Scale Deployment) and a large-scale emulation/simulation testbed in JP (**StarBE**D) realizes a single global edge-cloud networking testbed based on cutting-edge technologies with diversity and programmability.
- ✓ Use-case experiments on some realistic IoT applications running on the testbed involve the key functions developed in four tasks.
- ✓ Such testbed experiments can evaluate the feasibility and effectiveness of the proposed **Resilient Edge Cloud Designed Network**, and also clarify the remaining issues.

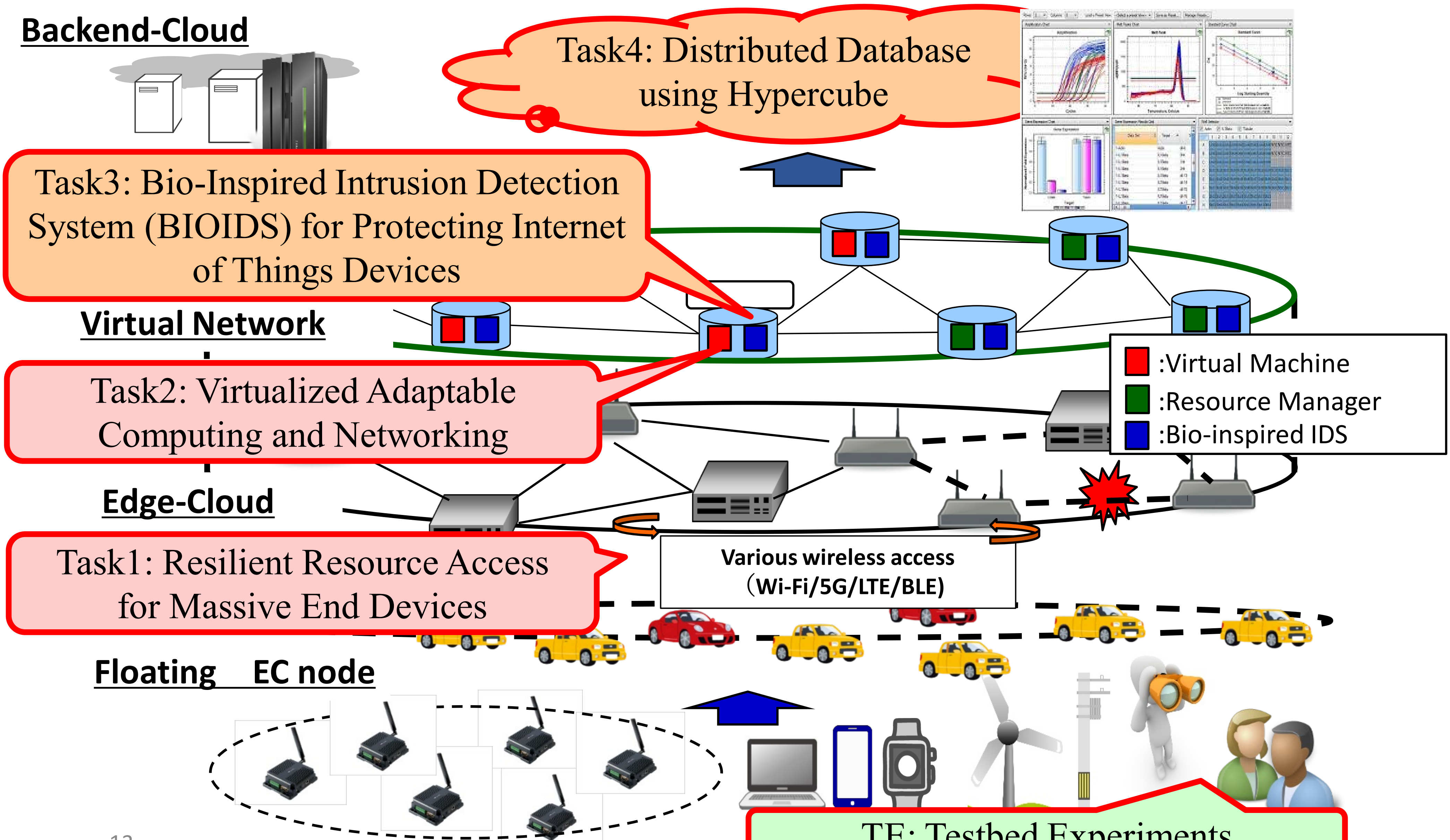
Milestones:

Year 1: Kyutech-RISE/StarBED/Seattle connections. Use-case applications selection.
Year 2: Kyutech-CCNY connection. Design and development of the experiments with feedbacks to each task.
Year 3: The total testbed experiments.

Task Members:

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

Summary



Backend-Cloud
Task4: Distributed Database using Hypercube
Task3: Bio-Inspired Intrusion Detection System (BIOIDS) for Protecting Internet of Things Devices
Virtual Network
:Virtual Machine
:Resource Manager
:Bio-inspired IDS
Task2: Virtualized Adaptable Computing and Networking
Edge-Cloud
Task1: Resilient Resource Access for Massive End Devices
Various wireless access (Wi-Fi/5G/LTE/BLE)
Floating EC node
TE: Testbed Experiments