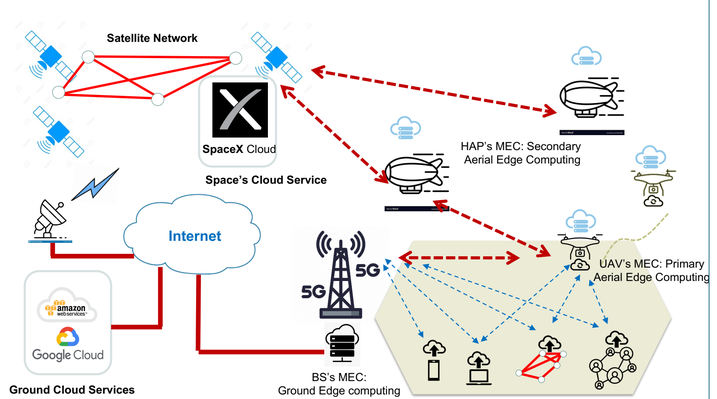
Cluster for Integrated Computation-Communication Platform (iCCL): Activities Updates

会津大学

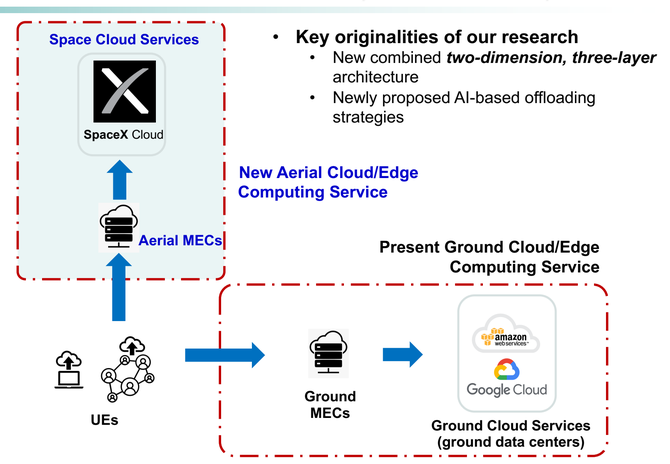
学際研究フォーラム 2025

UoA Joint Research Forum 2025

Space-Based Computation Concept



2D/3L Architecture: Computation in Space



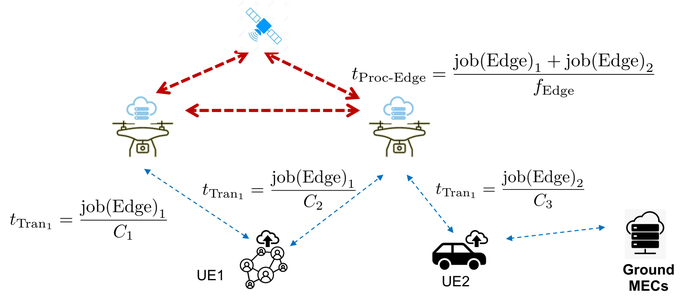
- **Key originalities of our research**
  - New combined ***two-dimension, three-layer*** architecture
  - Newly proposed AI-based offloading strategies

New Aerial Cloud/Edge Computing Service

Present Ground Cloud/Edge Computing Service

Computation Meets Communication

The joint design problem of communication, computation and the topology of communication/computation network



$$t = t_{\text{Tran}} + t_{\text{Prop}} + t_{\text{Queue}} + t_{\text{Proc.}}$$

Network Design Problems

- It becomes the joint problem of computation and communication

$$t = t_{\text{Tran}} + t_{\text{Prop}} + t_{\text{Queue}} + t_{\text{Proc.}}$$

- Computation: $t_{\text{Proc}} = t_{\text{Proc-device}} + t_{\text{Proc-Edge}} + t_{\text{Proc-Cloud}}$

$$t_{\text{Proc-device}} = \frac{\text{job}_{\text{device}}}{f_{\text{device}}} > t_{\text{Proc-Edge}} = \frac{\text{job}_{\text{Edge}}}{f_{\text{Edge}}} > t_{\text{Proc-Cloud}} = \frac{\text{job}_{\text{Cloud}}}{f_{\text{Cloud}}}$$

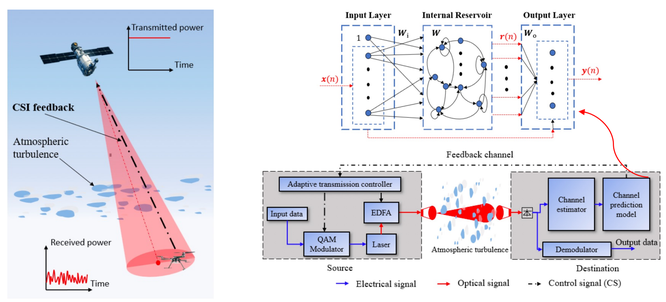
- Communication: $t_{\text{Tran}} = \frac{\text{job(Edge or Cloud)}}{C}$

The joint communication/computation problem: How much computation and where to perform it (local, edge or cloud) to achieve the best performance with constraints on network resources (CPU, energy, scalability etc.)

On-Going Research Topics

- PHY/MAC for interconnecting aerial edge computing platforms:
  - Advanced wireless, optical wireless ones using laser beams, and energy harvesting from radio frequency, solar energy, and laser; different communication architecture for the aerial backhauling using free-space optical communications interconnecting satellites, HAPs, UAVs, and ground stations.
- Architectures of edge computing from Space using MEC servers mounted on aerial BS platforms:
  - Design principles for deploying MECs in the integration between Space and ground networks to guarantee the service continuity, scalability and security.
- Optimization for integrated aerial edge computing/communications:
  - Focus on designing of network dynamicity, offloading strategies for UEs to meet different quality of service (QoS) requirements, from reliability, latency, data rates to energy consumption.
- Security for Space network
  - Satellite-based FSO/QKD network design
  - Physical layer security for VLC access networks

1. ML-based Optical Channel Prediction



"Adaptive Rate/Power Control with ML-based Channel Prediction for Optical Satellite Systems," ***IEEE Transactions on Aerospace and Electronic Systems***, vol. 60, no. 5, pp. 7498-7509, Oct. 2024

2. Multi-Agent DRL-Aided E2E NTN

- Goal: end-to-end performance optimization for mixed FSO/RF-aided Non-Terrestrial Networks

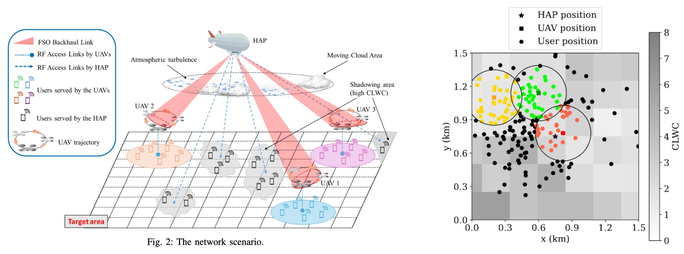
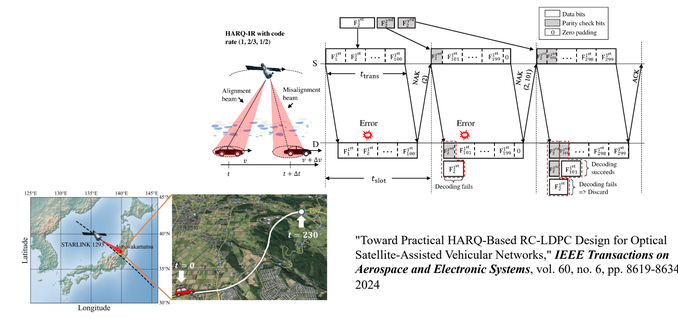


Fig. 2: The network scenario.

"DRL-Based End-to-End Optimization for Mixed FSO/RF Non-Terrestrial Networks," ***IEEE Transactions on Aerospace and Electronic Systems***, Submitted Mar. 2025

3. MAC Design: HARQ-based RC-LDPC

- Goal: design of HARQ with Incremental Redundancy for reliable Internet of vehicles



"Toward Practical HARQ-Based RC-LDPC Design for Optical Satellite-Assisted Vehicular Networks," ***IEEE Transactions on Aerospace and Electronic Systems***, vol. 60, no. 6, pp. 8619-8634, Dec. 2024

4. AI-Empowered Dual-Connectivity

Goal: jointly determination of
- Channel assignment (i.e., the user association) for MEC servers
- Resource management for communication (e.g., bandwidth allocation)
- Computation (e.g., CPU frequency selection for local and remote computing) at the server and the user.

- Multi-MECs: UAV-based MECs offering additional computing service
- Multi-user with dua-connectivity

"Deep Reinforcement Learning-Based Online Resource Management for UAV-Assisted Edge Computing With Dual Connectivity," in ***IEEE/ACM Transactions on Networking***, vol. 31, no. 6, pp. 2761-2776, Dec. 2023

5. AI-Empowered Network Control

Goal: effective method for **adaptive 3D placement** of **multiple UAV-BSs** to improve the QoE of users in a **large-scale dynamic network,** where the users move continuously and have heterogeneous traffic.

"Adaptive 3D Placement of Multiple UAV-Mounted Base Stations in 6G Airborne Small Cells with Deep Reinforcement Learning," *IEEE/ACM Tran. on Networking*, Submitted in Aug. 2024

6. Key Reconciliation for Satellite-based FSO/QKD Systems

- Goal: effective design of a blind key reconciliation
  - To obtain a high secret key rate over fluctuating QBER

"Blind Reconciliation with Protograph LDPC Code Extension for FSO-Based Satellite QKD Systems," ***IEEE CSNDSP***, Rome, Italy, Jul. 2024 **(Best Paper Award)**

"Toward Practical HARQ-Based RC-LDPC Design for Optical Satellite-Assisted Vehicular Networks," ***IEEE Transactions on Aerospace and Electronic Systems***, July 2024. doi: 10.1109/TAES.2024.3434768.

Main Research Collaborators

UK
- Northumbria University: VLC
- University of Bradford: FSO
- University of Southampton: QKD, FSO

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- India Institute of Technology (IIT) – Roorkee, India: QKD

Japan
- Shizuoka University: VLC
- Tokyo University: QKD
- NICT: Satellite experiment

Vietnam
- Hanoi University of Science and Technology: Computing
- Posts & Telecommunications Institute of Technology : FSO
- Danang University of Science and Technology: Computing

iCCL Cluster: Sponsors and Funding

Our Team (iCCL)

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  - Dr. IBRAHIM Ìdnin, Associate Professor
  - Dr. VIGLIETTA Giovanni Associate Professor
- Students
  - Graduate students (PhD/MS): 07
  - Undergraduate research assistants: 06
- Number of graduated PhDs (since 2005): 11