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Advanced Solutions for 6G Satellite Systems Workshop

IEEE

IEEE Future NETWORKS

The Role of NTN in 6G

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Designations

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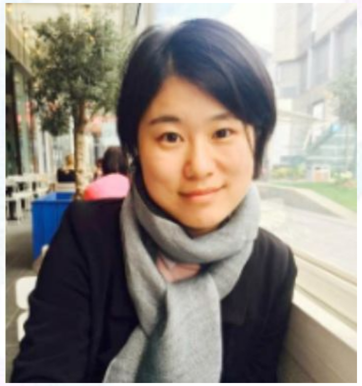
Who we are

Prof. Tasos Dagiuklas

Professor in London South Bank University
Lead of the Research Centre for Cognitive Systems
He has over 20 years of experience in telecommunications
Research Interests: Smart Internet Technologies, 5G/6G, Programmable Networks, UAVs



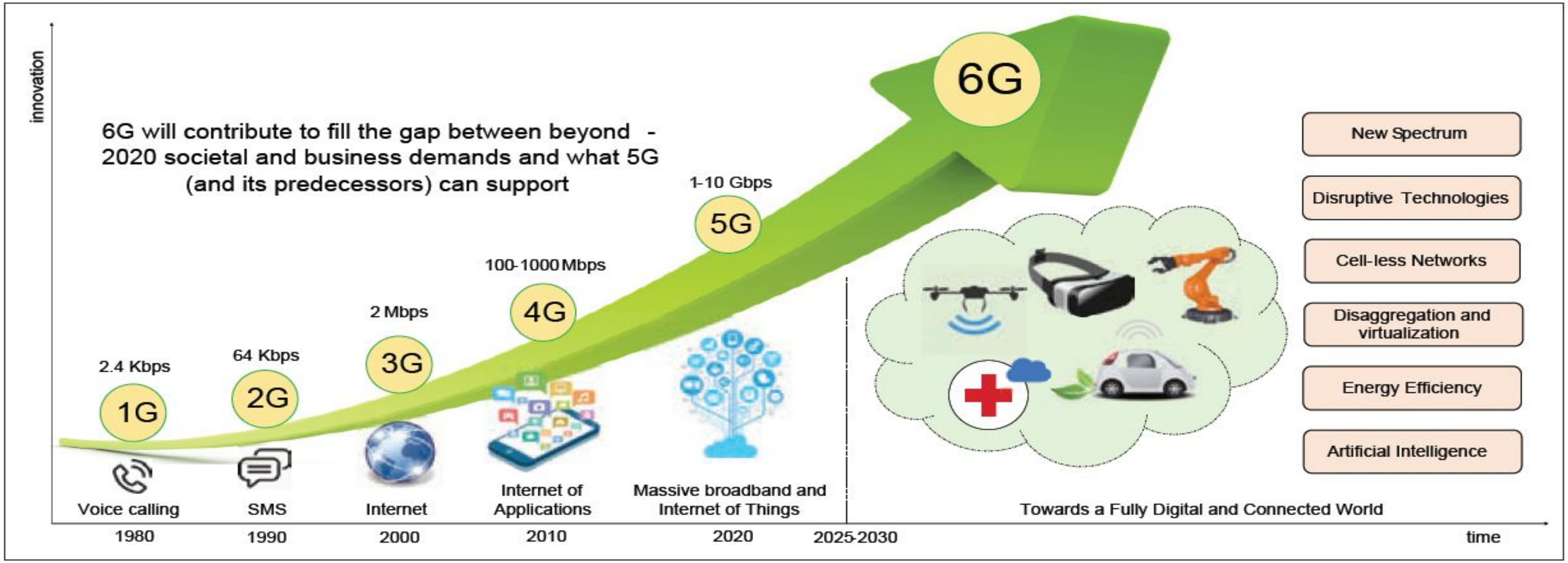
Dr. Yongxu Zhu

Senior Lecturer in London South Bank University.
She has served as Editor of the IEEE Transactions on Wireless Communications, IEEE Transactions on Green Communications and Networking, IEEE Wireless Communication Letters. Her research interests include Artificial Intelligence for Communications, UAV Communications, Wireless Edge Caching Networks and Physical layer security.

AGENDA

- Why 6G & 6G Vision
- NTN Research Challenges
- Potential solutions & Applications

Why 6G?

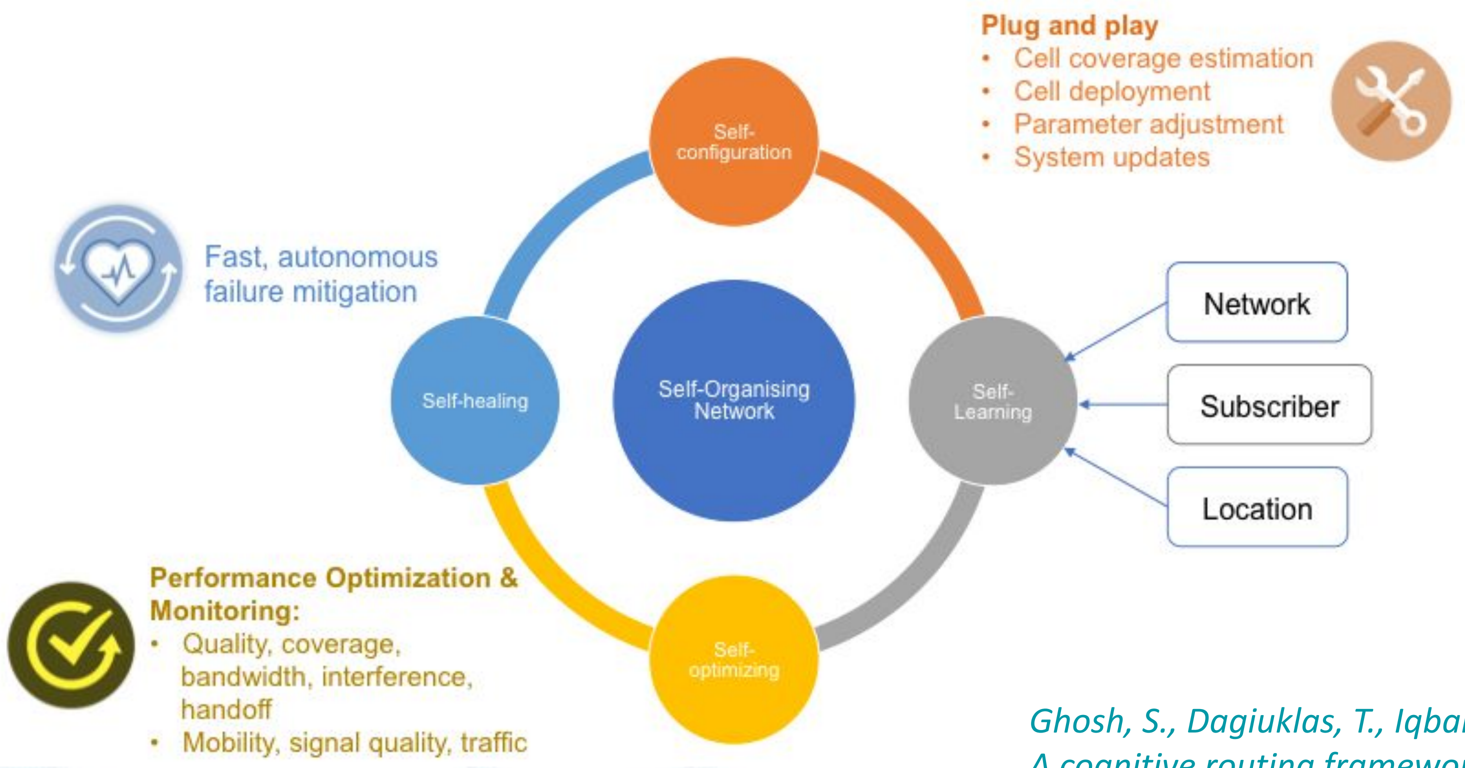


*Source: M. Giordani, et al., "Toward 6G Networks", **IEEE Communications Magazine** , March 2020*

6G Vision

- Meet **novel network demands** in a holistic fashion, covering the new needs of economic, social, technological, and environmental context of the 2030 era
- Mobile to Enable Proliferation of AI
- Collaborative ML
- **integration** of the space, terrestrial, and Non-Terrestrial Networks
- **large range of applications and services**:
  - AR/VR, Holographic tele-presence, Industry 5.0 and robotics,
  - Telepresence -high resolution imaging and sensing, haptic communication, Metaverse
  - Autonomous connected vehicles , massive URLLC (mURLLC), human-centric services, bio-Internet of things (B-IoT).

Knowledge Defined Networks



Ghosh, S., Dagiuklas, T., Iqbal, M. and Wang, X., 2022. A cognitive routing framework for reliable communication in IoT for industry 5.0. IEEE Transactions on Industrial Informatics, 18(8),

SON-KDN cycle

NTN in Future Networks

- It refers to a network which provides communication services through a flying vehicle
  - Geostationary earth orbit (GEO), Medium earth orbit (MEO), and LEO satellites,
  - Airborne vehicle (i.e., HAPs, UAVs and drones)
- It provides connectivity in unreachable areas for a terrestrial network (i.e., vessels and airplanes), or remote areas (i.e., rural areas)
- Different NTN architecture options
  - NTN platform as a user
  - NTN platform as a relay
  - NTN platform as a BS
  - Mixed Architectures

3GPP NTN

- In 2018
  - Integration of satellite and terrestrial networks
  - Spaceborne (GEO, LEO, MEO) and airborne (HAPS, UAV)
- 3GPP Release 17: Integration of NTN with mobile networks
  - Improve service continuity and mobility
  - Enabling satellite to access a 5G ecosystem to reduce costs
- 3GPP release 18
  - NTN-TN and NTN-NTN mobility and service enhancements
  - Network-based UE location

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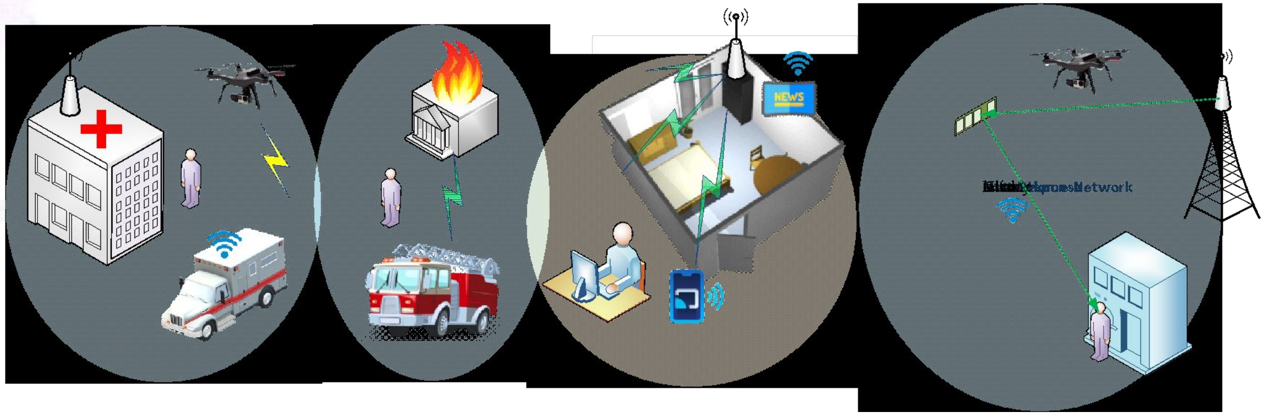
- Why 6G & 6G Vision
- **NTN Research Challenges**
- Potential solutions & Applications

NTN Research Challenges

- Smart NTN with edge computing and storage capabilities
- Architecture design as a single access network
- Energy efficiency and path planning
- Security Requirement

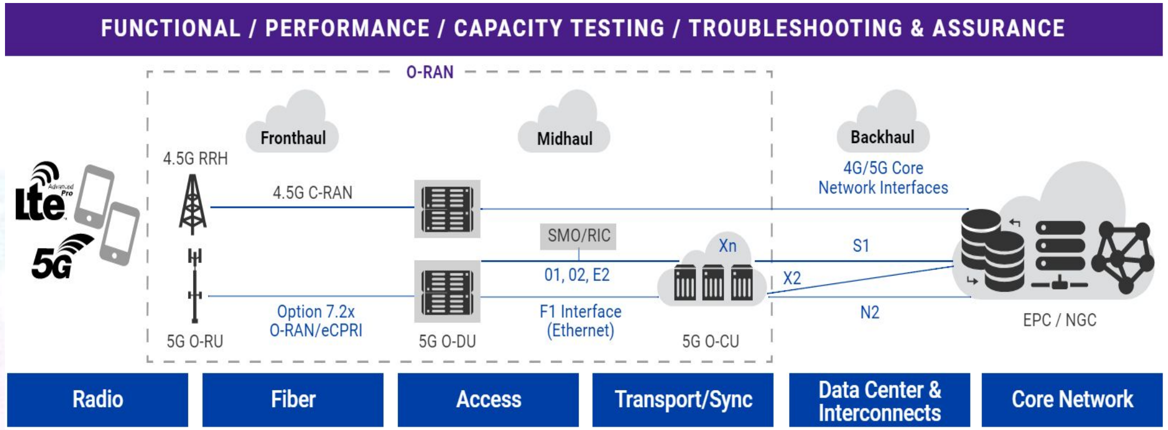
Edge computing and storage capabilities

- Variety of edge scenes
- Major benefits for edge solutions:
  - low latency
  - high bandwidth
  - device processing and data offload
  - trusted computing and storage.

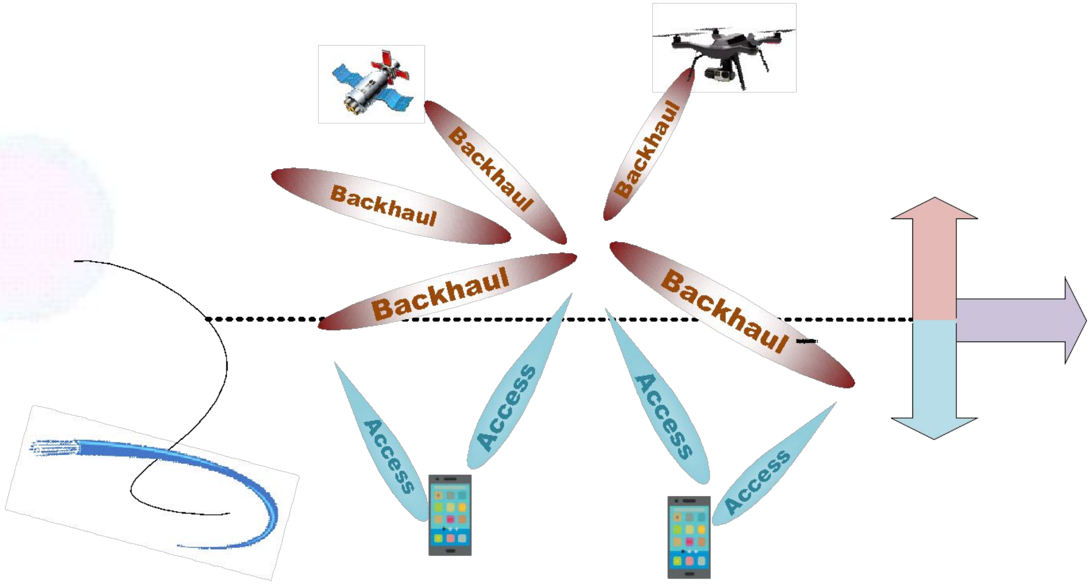


Architecture design as a single access network

- Core: Integrated O-RAN Architecture

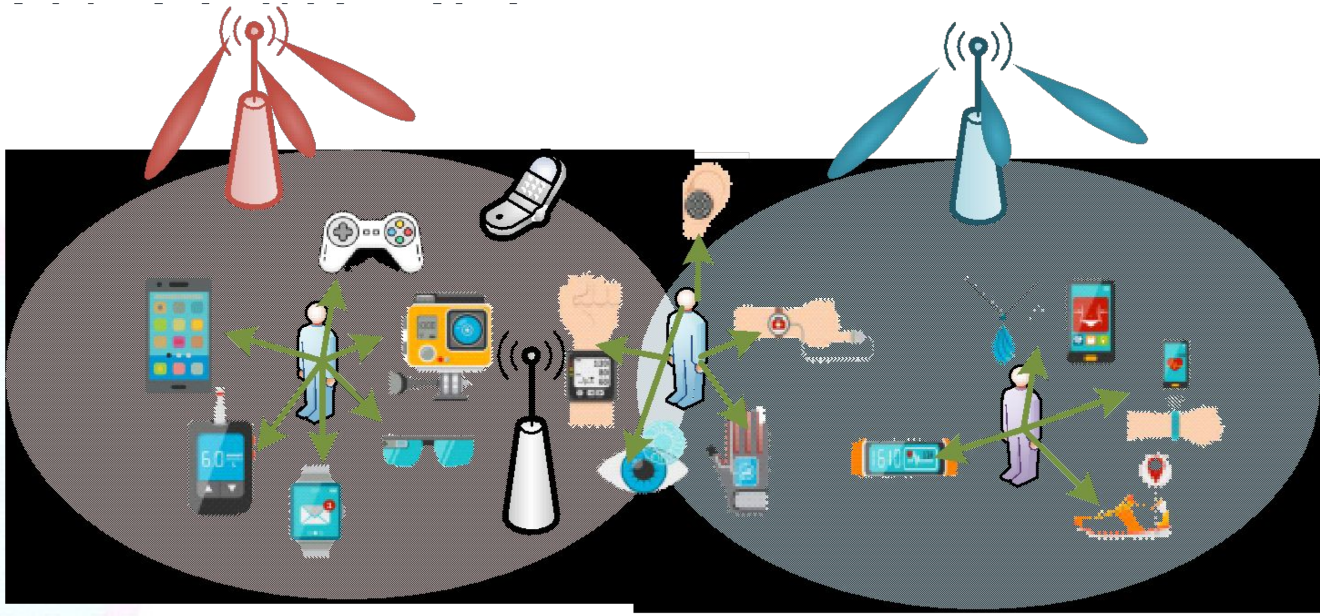


- Access: Distributed/ Hybrid network Architecture

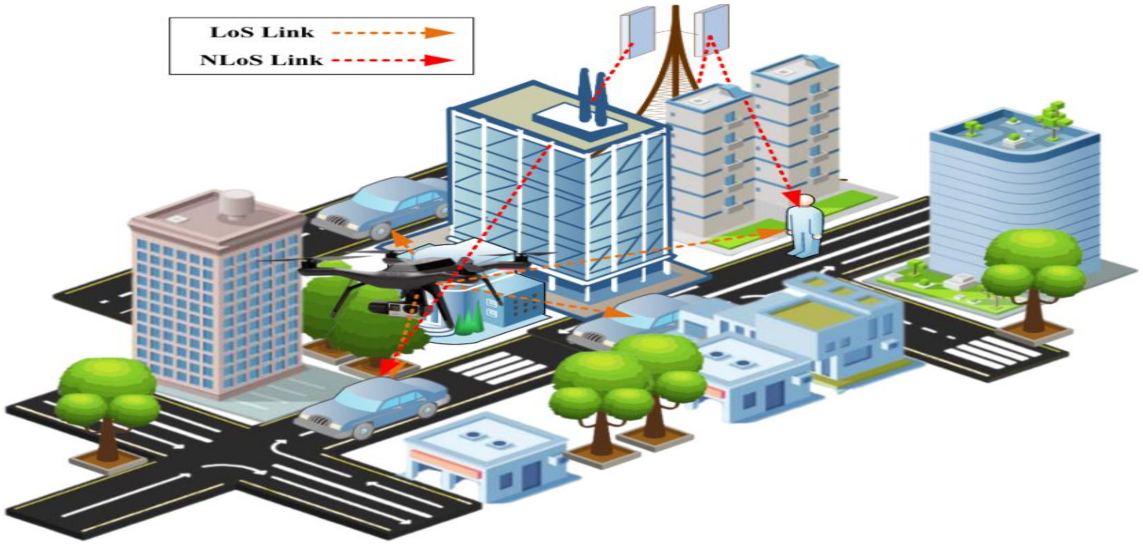


Energy efficiency and path planning

- Ultra Densification



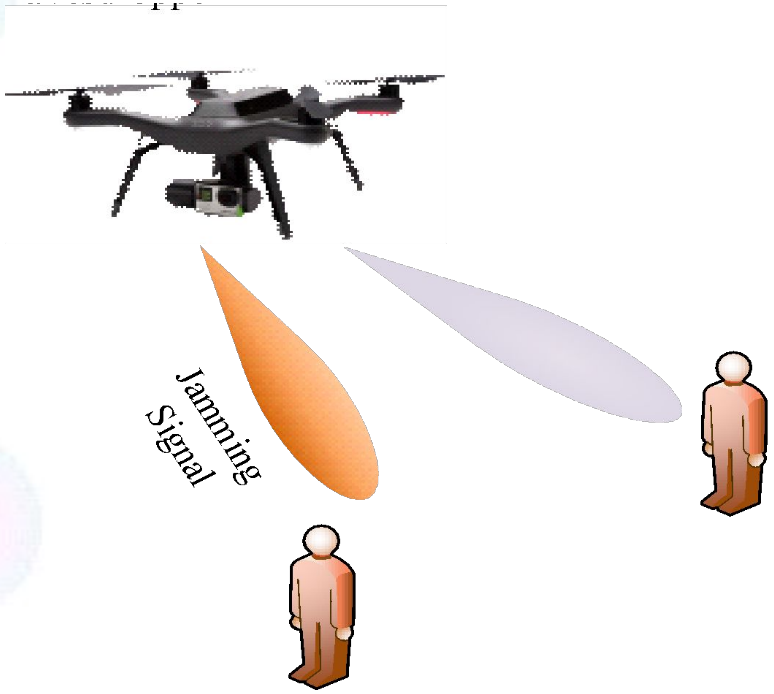
- Blocking in



Security requirement with

- **Cost-effective and Secure mechanism**

- **Design of decentration authority making secure network/communication decisions**



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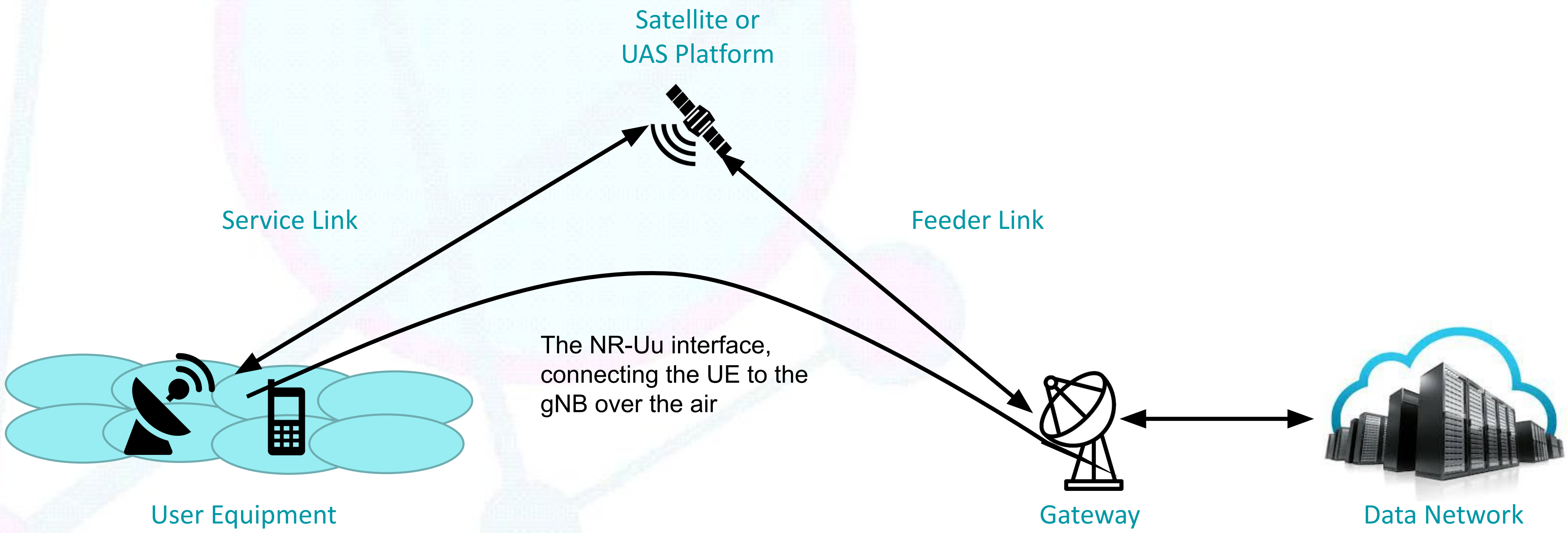
- **Potential solutions & Applications**

NTN-based NG-RAN Architectures

- Transparent Architectures
- Regenerative Architectures

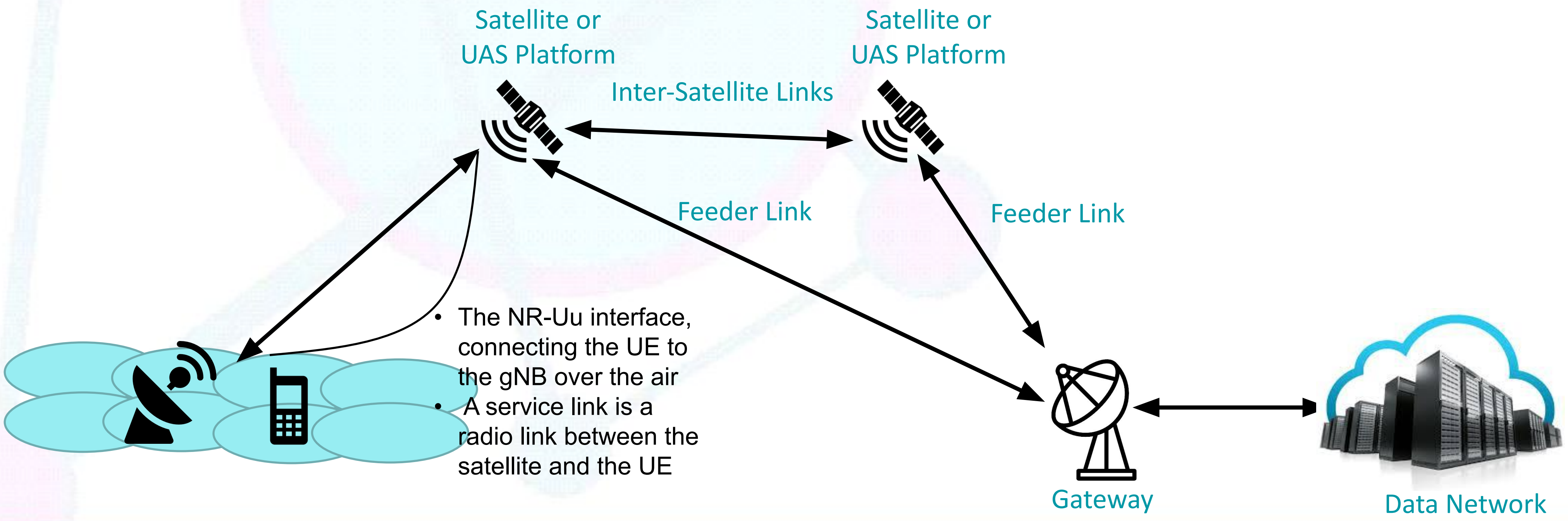
Transparent Architectures

- It uses the NR-Uu radio interface from the feeder link (between the NTN gateway and the satellite) to the service link (between the satellite and the UE) and vice versa
- The NTN GW supports all necessary functions to forward the signal of NR-Uu interface



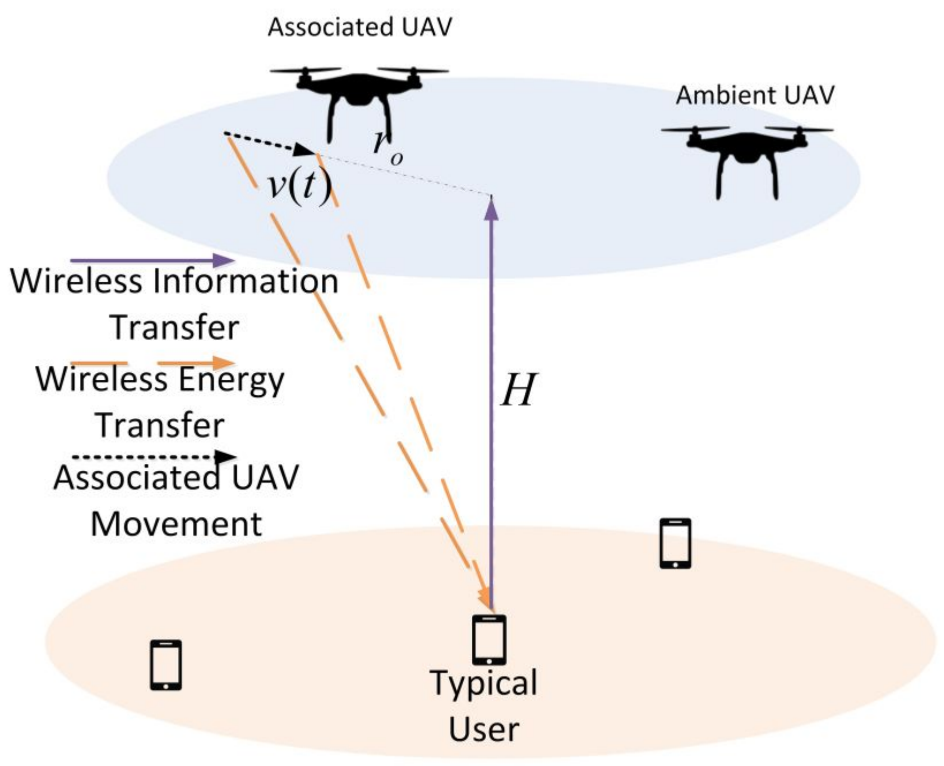
Regenerative Architectures

- It implements regeneration of the signals received from Earth.
- The NR-Uu radio interface is used on the service link between the UE and the satellite.
- Satellite Radio Interface (SRI) is used on the feeder link between the NTN gateway and the satellite.



Energy harvesting in LAPS (Drone & UAV)

- Dynamic adaptive flight scheme for downlink wireless power transfer and uplink information transfer architecture.
- Optimize the Spectrum Efficiency (SE) and Energy Efficiency (EE) of UAV-BSs and ground IoT networks, the UAV-BSs first transfer energy and then collect data from the ground IoT devices.

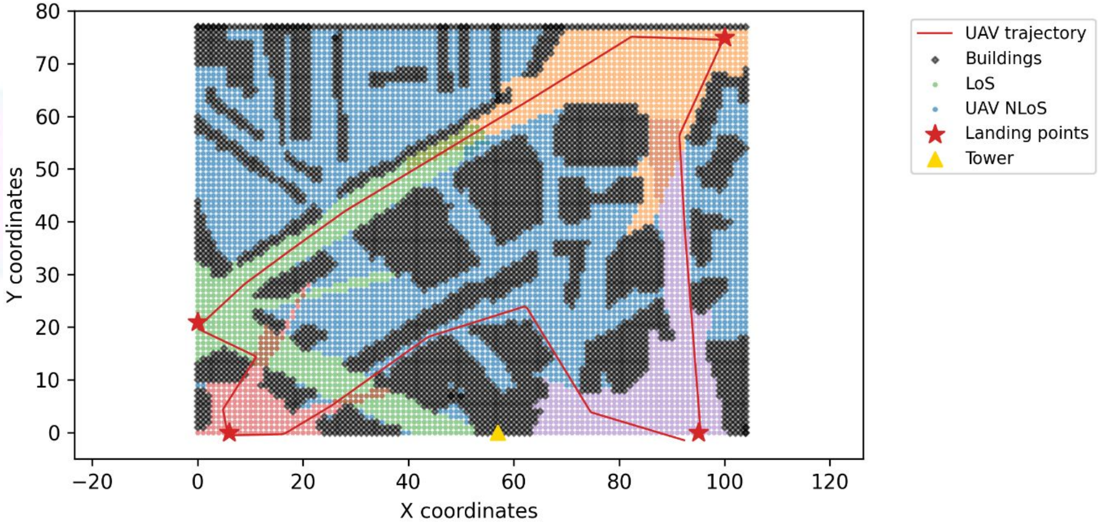


$$\mathbb{P}: \max_{\tau} \mathcal{B}_{\mathrm{EE}}^{\mathrm{Low}}(\tau, r_o) = \int_0^{r_{\mathrm{m}}(\tau)} \frac{R(r_o,\tau)}{\mathcal{E}_{\mathrm{F}}(r_o,\tau)+\mathcal{E}_{\mathrm{O}}(\tau)} f(r_o)\, dr_o$$

[ ] **Zhu, Yongxu**, Gan Zheng, Kai-Kit Wong, and **Tasos Dagiuklas**. "Spectrum and energy efficiency in dynamic UAV-powered millimeter wave networks." *IEEE Communications Letters* 24, no. 10 (2020): 2290-2294.

Dynamic Coverage

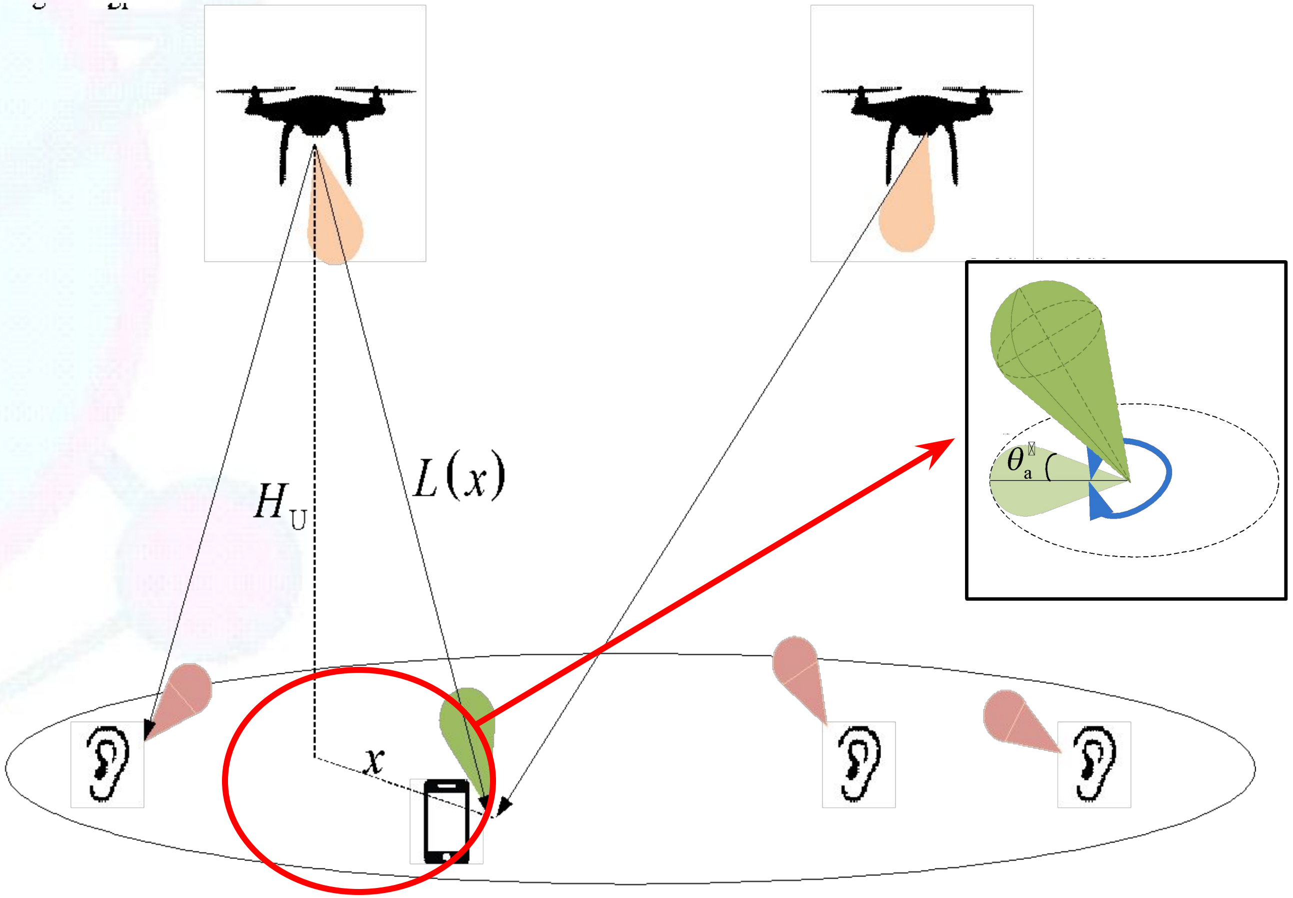
- Optimize the UAV trajectory to get maximize the Area Spectral Efficiency (ASE) of the air-to-ground system
- We use LoS queries approach to estimate the coverage area between UAV-enabled BS with ambient static device terminals.
- The realistic 3D geographical map in LSBU.



[2] Lorenzo De Simone, **Yongxu Zhu**, **Tasos Dagiuklas**, '*Incomplete Information based Coverage Optimization Approach in Aerial-Ground Integrated Wireless Networks*', will submit to IEEE Communication Letter.

UAV Security

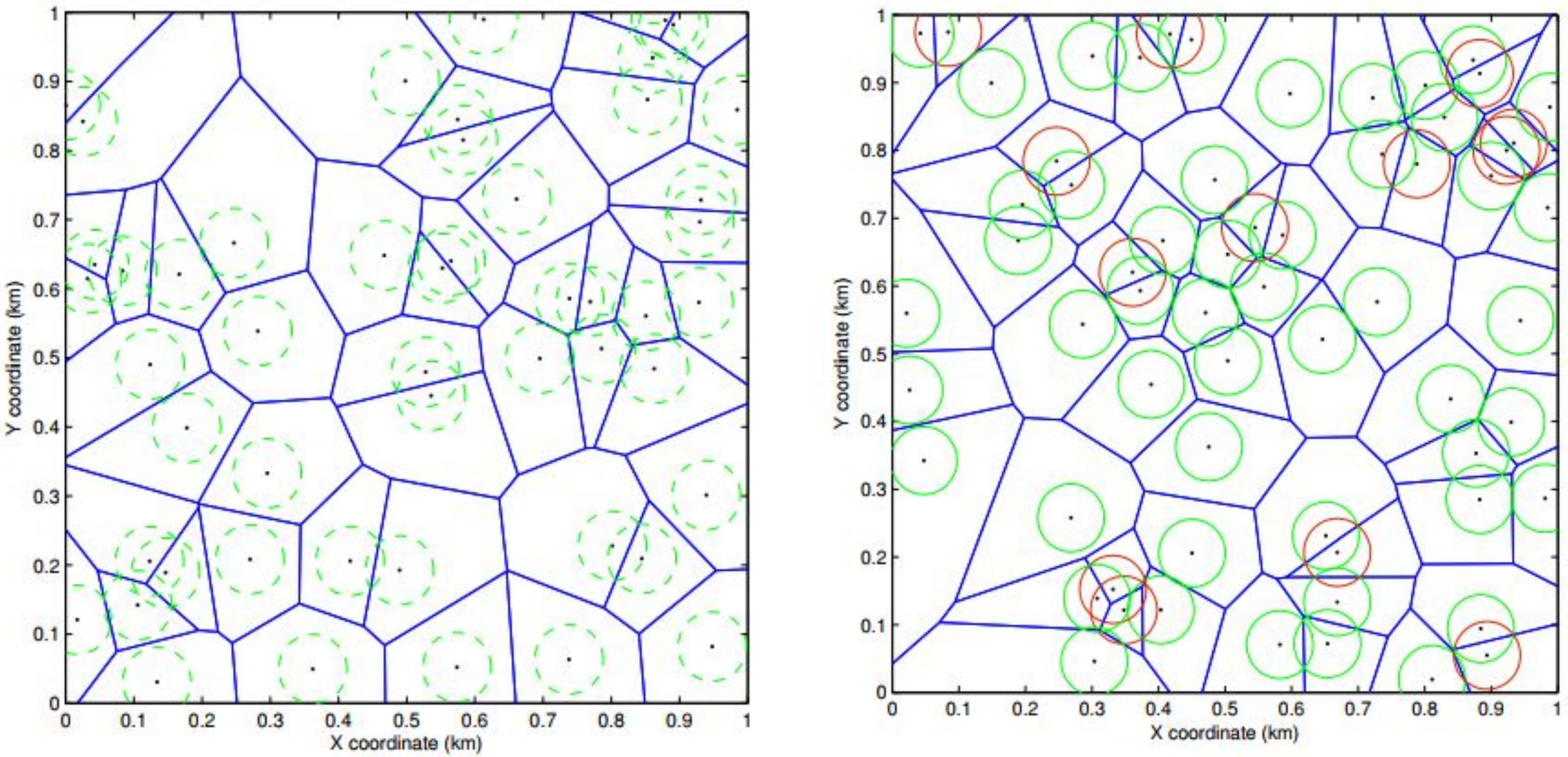
- The transmit jamming strategy can improve the secrecy performance in air to ground network, the jamming signal enable to confound the eavesdroppers
- 3D antenna gain in the air-to ground links will be more practical.



Zhu, Yongxu, Gan Zheng, and Michael Fitch. "Secrecy rate analysis of UAV-enabled mmWave networks using Matérn hardcore point processes." *IEEE Journal on Selected Areas in Communications* 36, no. 7 (2018): 1397-1409.

Network Deployment

- Uses the Matern hardcore point process to guarantee the safety distance between the randomly deployed UAV base stations.

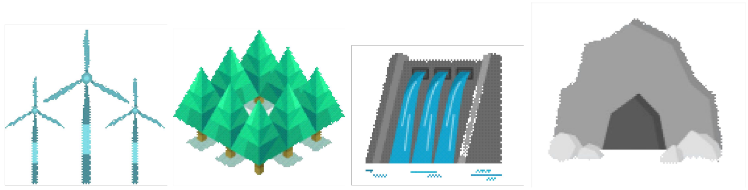


(a) PPP with $\lambda_P = 50/km^2$.

(b) MHC point process with $\lambda_U = 50/km^2$, $\rho = 50m$.

Zhu, Yongxu, Gan Zheng, and Michael Fitch. "Secrecy rate analysis of UAV-enabled mmWave networks using Matérn hardcore point processes." *IEEE Journal on Selected Areas in Communications* 36, no. 7 (2018): 1397-1409.

Use-Cases



- Urban Areas:
  - Backhauling
  - IoT Connectivity
  - Event Coverage
- Rural Areas
  - Backhauling
  - Tracking
  - Direct Connectivity
- Remote Areas
  - Maintain connectivity over trains, boats, planes
  - Public Safety and Emergency
  - Aeronautical Broadband

Thank you so much!

Q&A