Distributed Edge Intelligence with Integrated Terrestrial and Non-Terrestrial Networks in 6G

4th India Spectrum Management Conference, 7-8th November 2024

BITS Pilani
Hyderabad Campus

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About

Birla Institute of Technology and Science Pilani

- 5 campuses (4: India, 1: Dubai)
- ≅ 18,000 Students
- ≅ 950 Faculty Members

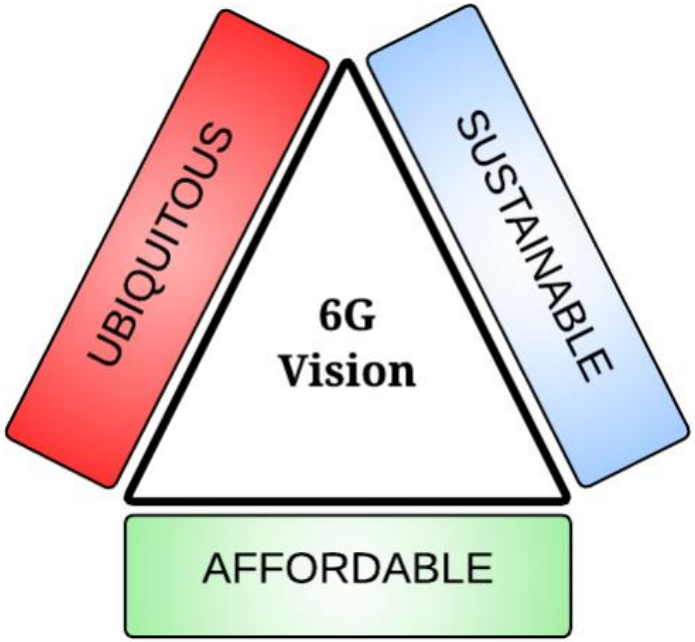
Department of Computer Science and Information Systems (Hyderabad Campus)

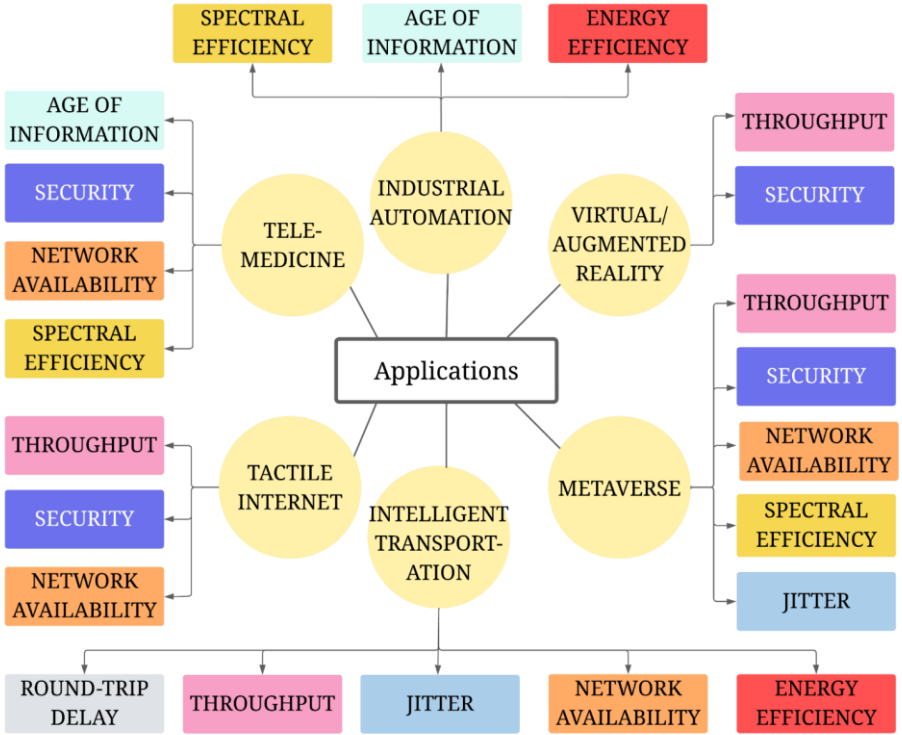
- 26 Faculty Members
- 64 PhD Students

VIDVAN: Vital Intelligence for Dynamic and Versatile Advanced Networking Research Group

- 6G and Wireless Networks
- Non-terrestrial Networks
- Edge and Distributed Computing

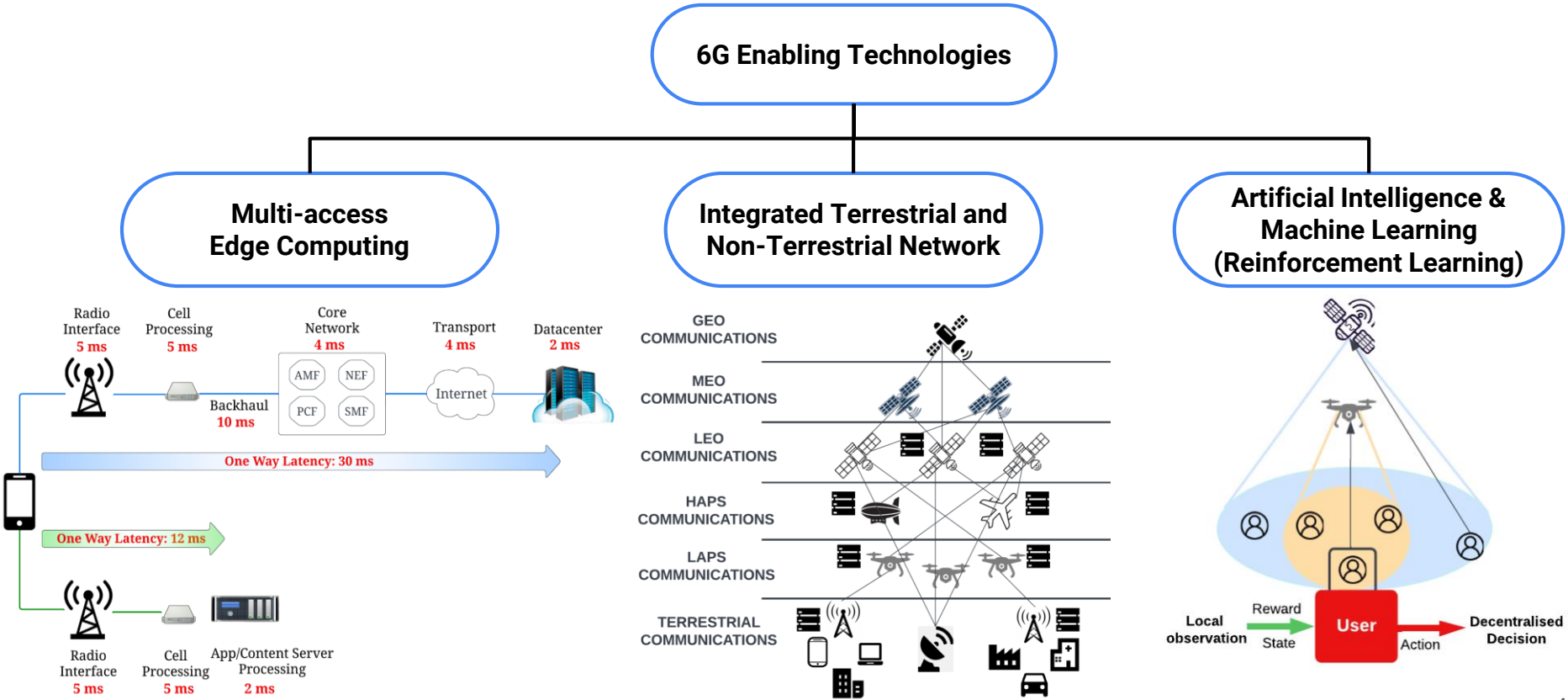
6G: Vision, Applications and their KPI Requirements





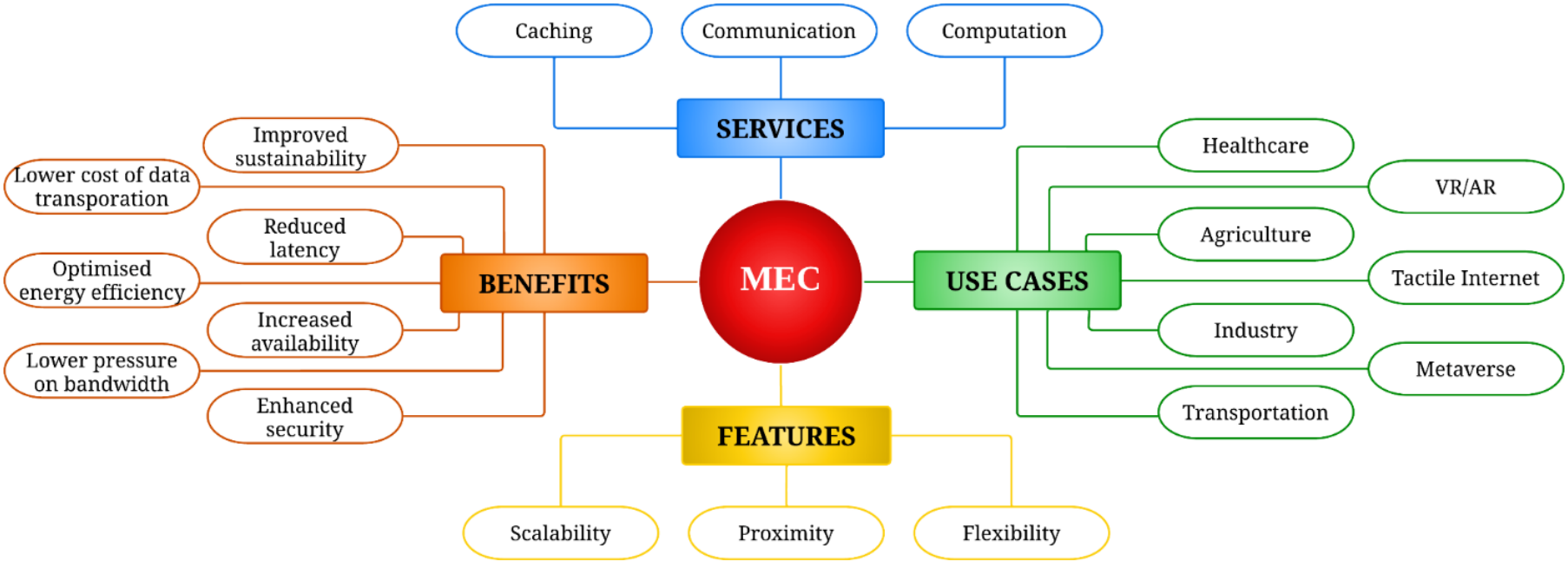
1. https://dot.gov.in/sites/default/files/Bharat%206G%20Vision%20Statement%20-%20full.pdf
2. Nida Fatima, Paresh Saxena, and Giovanni Giambene. (2023). Deep reinforcement learning based computation offloading for xURLLC services with UAV-assisted IoT-based multi-access edge computing system. Wireless Networks, pp. 1–17. DOI: https://link.springer.com/article/10.1007/s11276-023-03596-y

6G Enabling Technologies



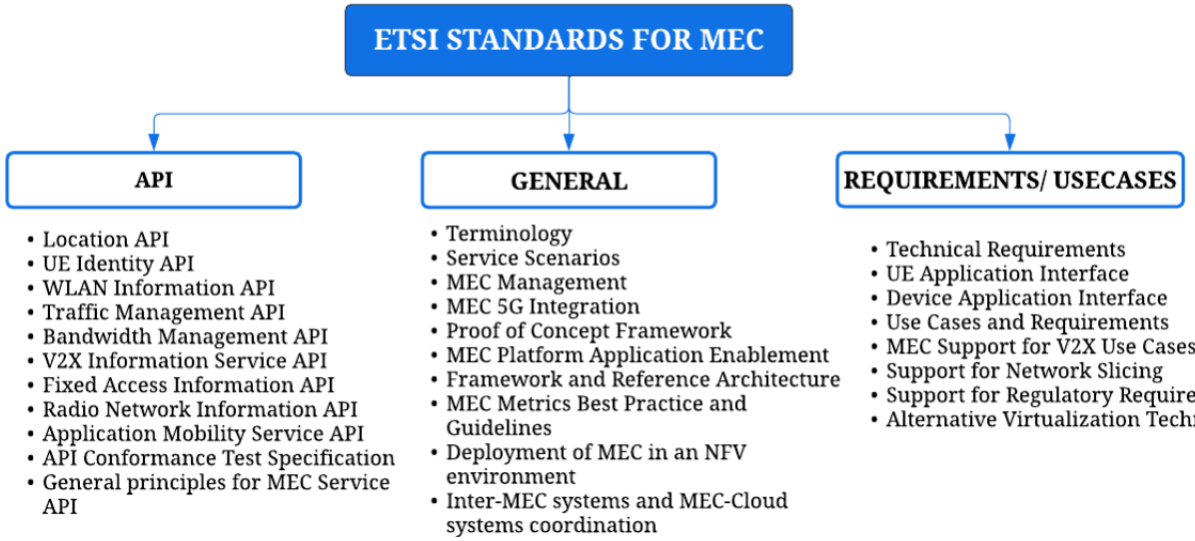
4. https://dot.gov.in/sites/default/files/Bharat%206G%20Vision%20Statement%20-%20full.pdf

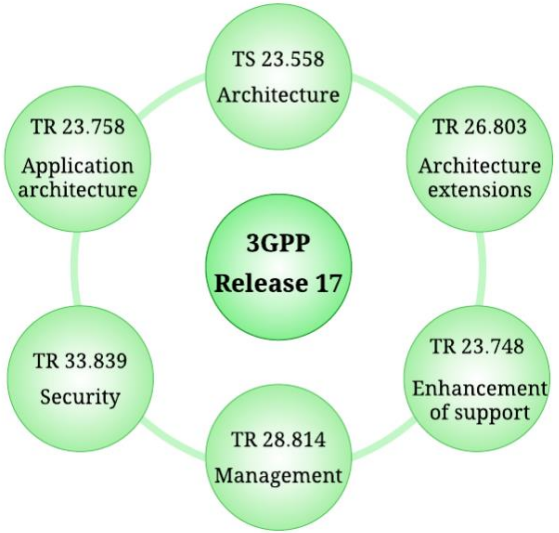
Multi-Access Edge Computing: Scope

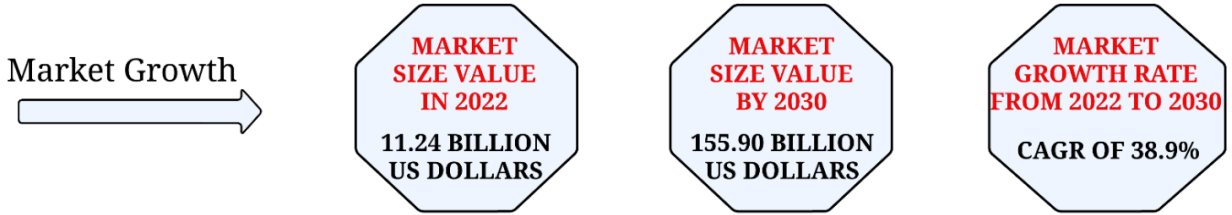


5. Nida Fatima, Paresh Saxena, and Manik Gupta. (2022). Integration of multi access edge computing with unmanned aerial vehicles: Current techniques, open issues and research directions. Physical Communication, Vol. 52, pp. 101641. DOI: https://doi.org/10.1016/j.phycom.2022.101641

Multi-Access Edge Computing: Standardization and Market Growth

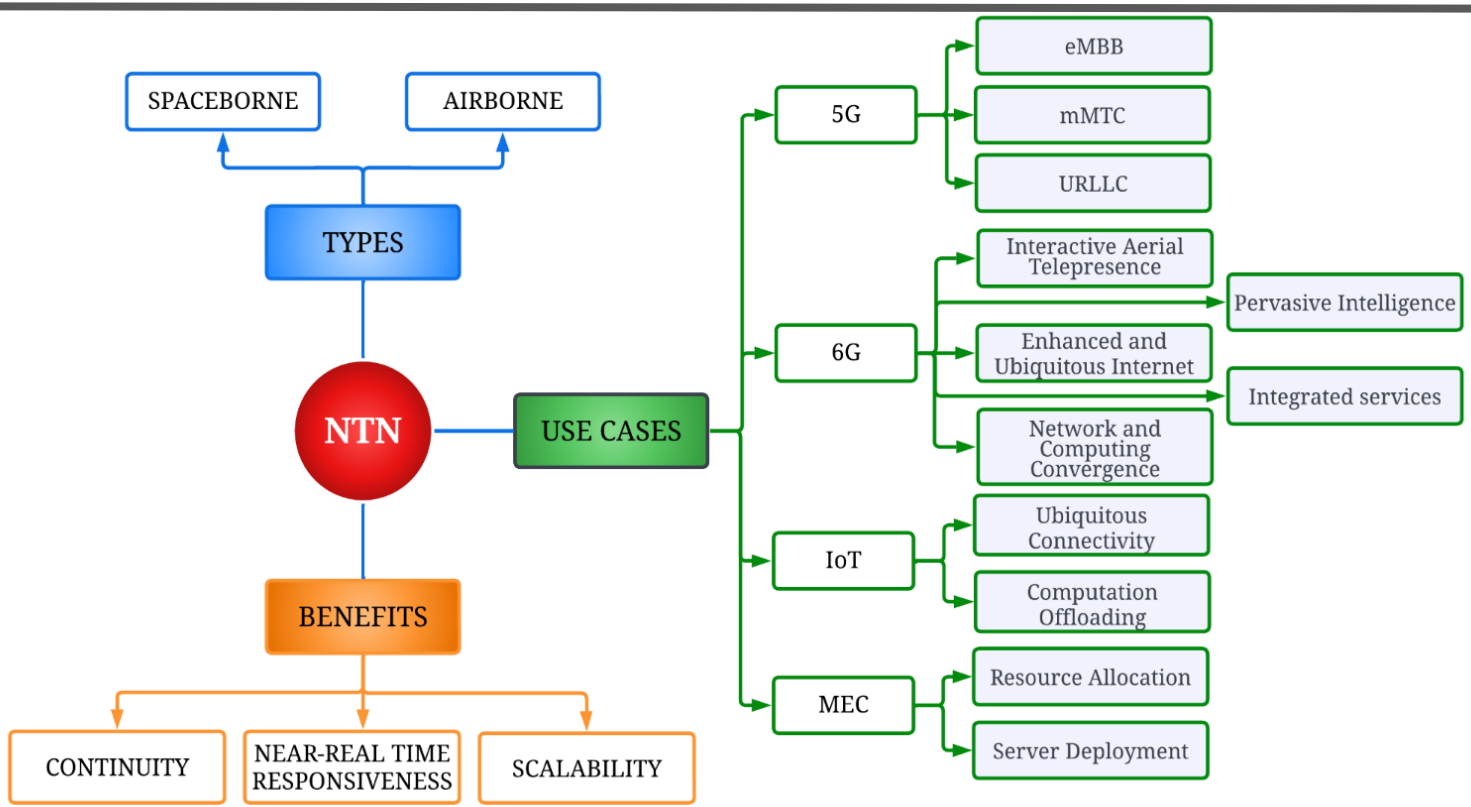






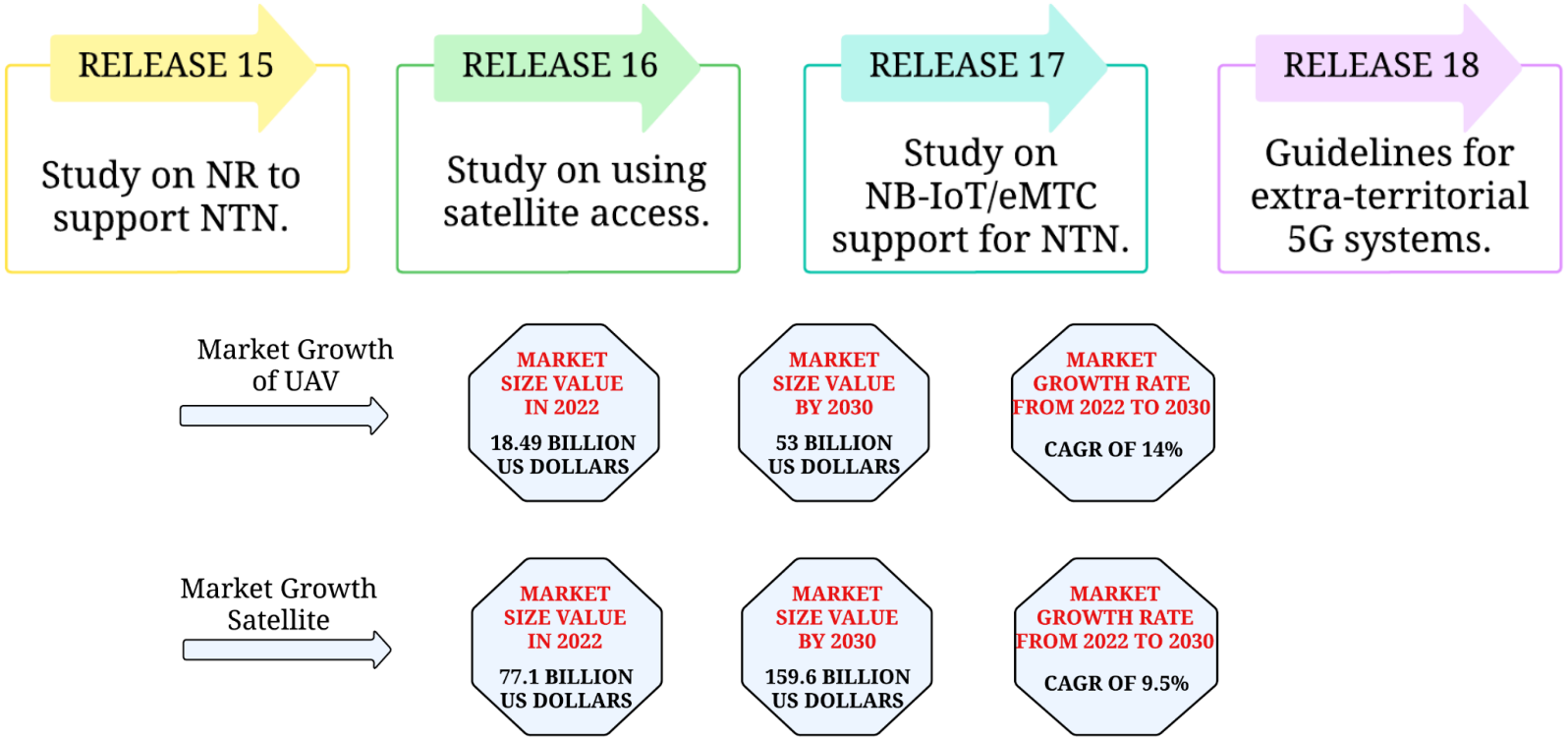
6.https://www.globenewswire.com/en/news-release/2022/07/07/2475942/0/en/Edge-Computing-Market-Size-to-Hit-at-USD-116-5-Billion-by-2030.html
7. https://www.3gpp.org/news-events/3gpp-news/edge-sa6

Non-Terrestrial Networks: Scope



8. Giordani, Marco, and Michele Zorzi. "Non-terrestrial networks in the 6G era: Challenges and opportunities." IEEE network 35.2 (2020): 244-251.

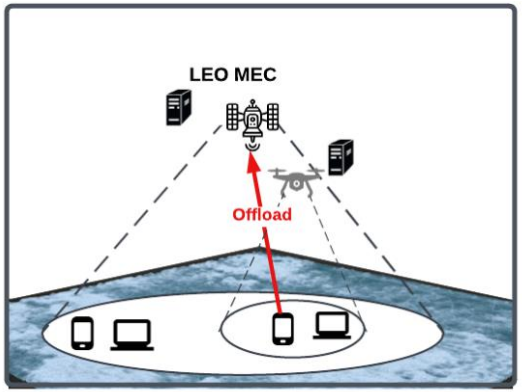
NTNs: Standardization and Market Growth



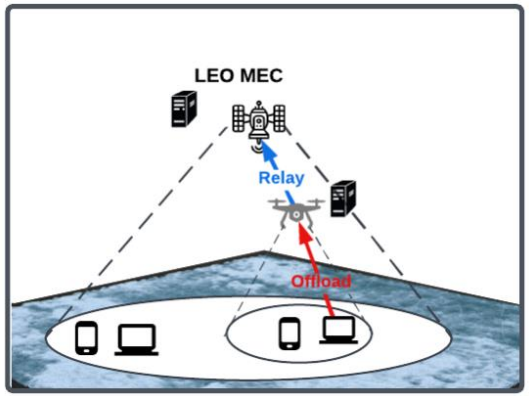
9. https://www.3gpp.org/news-events/partner-news/ntn-rel17
10. https://www.globenewswire.com/news-release/2024/10/09/2960744/0/en/Unmanned-Aerial-Vehicle-UAV-Market-Valuation-Skyrocketing-to-Reach-US-119-71-Billion-By-2032-Astute-Analytica.html

Computation Offloading in NTN-empowered MEC

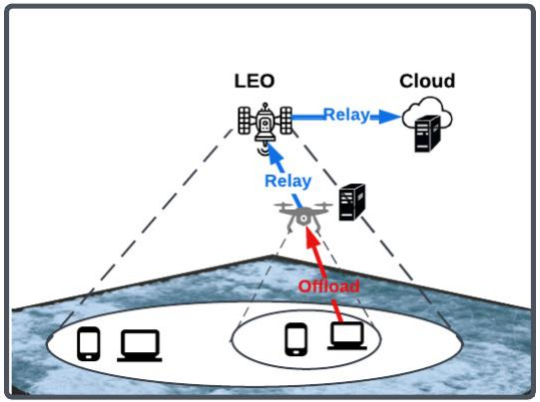
User can offload task to either **LEO MEC or UAV MEC.**



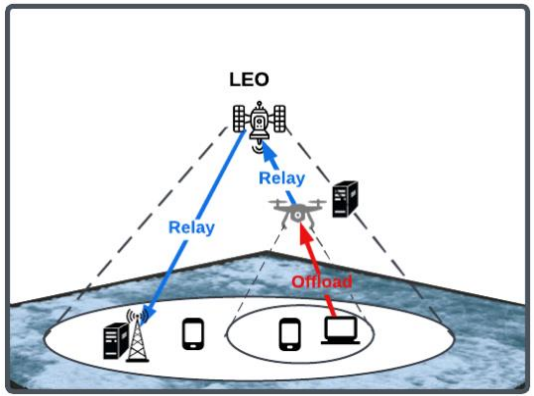
UAV MEC can perform computation and relay offloaded task to **LEO MEC.**



LEO to **relay** offloaded task to **Cloud.**



LEO to **relay** offloaded task to **Terrestrial MEC.**



11. Nida Fatima, and Paresh Saxena. (2022). Distributed Deep Reinforcement Learning for Computation Offloading in MEC enabled TNTNs. In IEEE Advanced Solutions for 6G Satellite Systems Workshop.

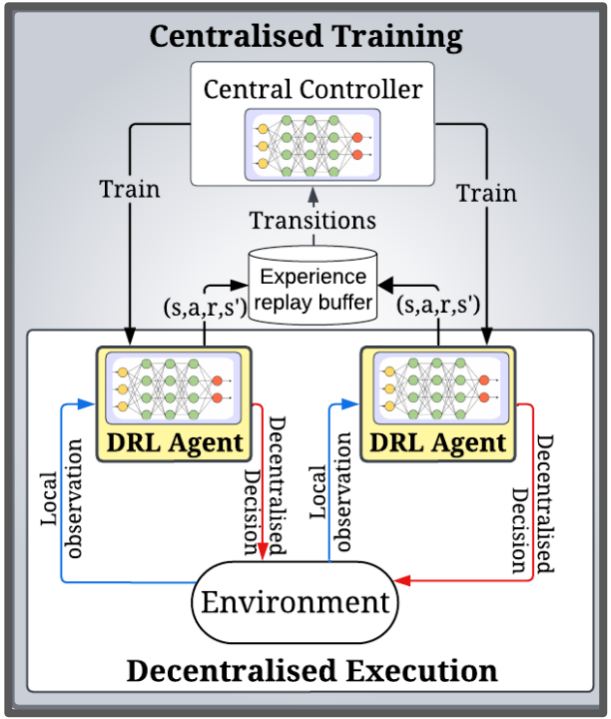
Methodology for finding Computation Offloading Strategy

Methodology	Explanation	Connection with the work
Reinforcement Learning (RL)	RL excels in making decisions in uncertain environments without prior knowledge of the system.	Each UE acts as an agent and does not have the complete information of the environment.
Deep RL (DRL)	DRL utilizes deep neural networks to obtain the optimal policy. Highly suitable for dynamic and large scale environments	The considered environment is both large scale and dynamic, hence utilization DRL is essential.
Multi-Agent DRL (MADRL)	MARL is adopted when multiple agents are involved.	The considered environment has multiple UEs taking offloading decisions simultaneously, hence MARL is used.
MA Distributed DRL (MADDRL)	Decentralised approach enables agents to make decisions independently.	Each UE follows a distributed appraoch by taking the offloading decision using its local observation.

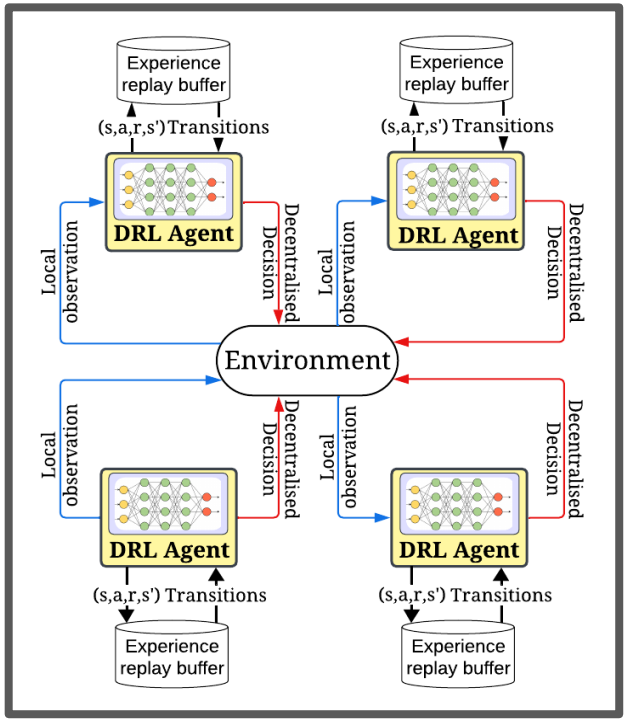
12. Zhang, Kaiqing, Zhuoran Yang, and Tamer Başar. "Multi-agent reinforcement learning: A selective overview of theories and algorithms." Handbook of reinforcement learning and control (2021): 321-384.

Multi-agent Distributed Deep Reinforcement Learning

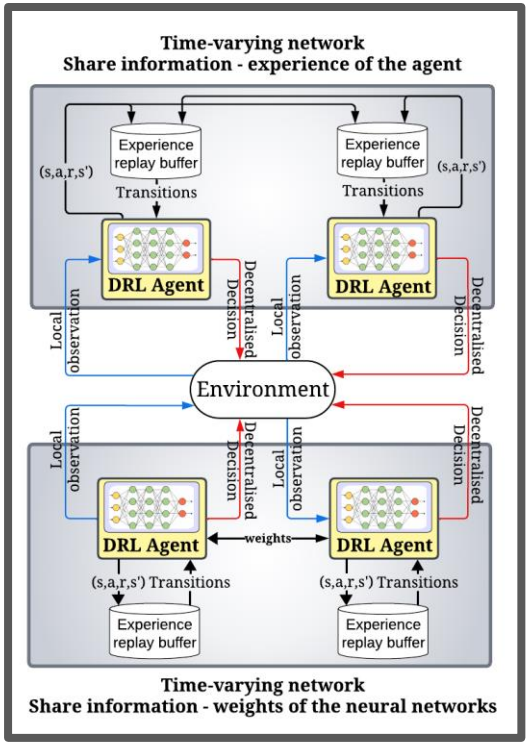
Centralised Training and Decentralised Execution



Independent Learners



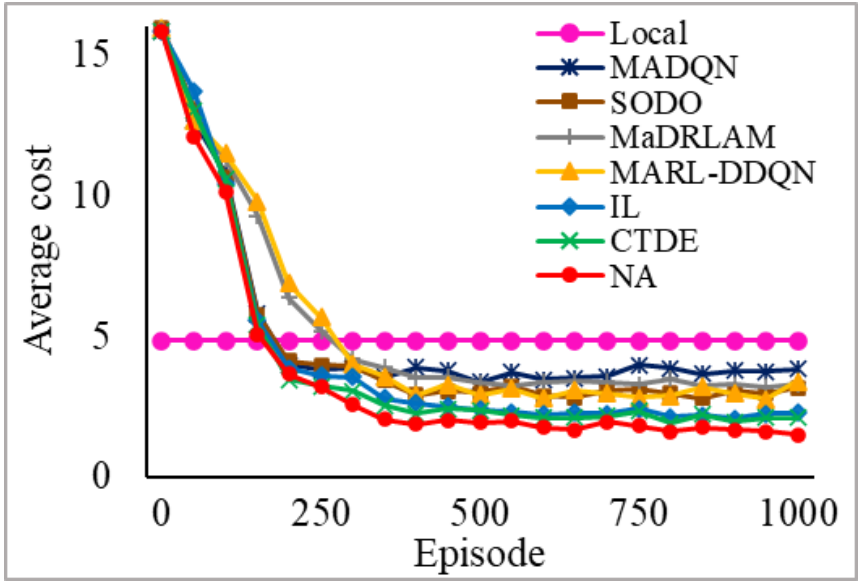
Networked Agents



13. Nida Fatima, Paresh Saxena, and Giovanni Giambene. (2023). Distributed Deep Reinforcement Learning for Latency Optimized Computation Offloading in Aerial-Assisted MEC Networks. IEEE Future Networks Tech Focus.

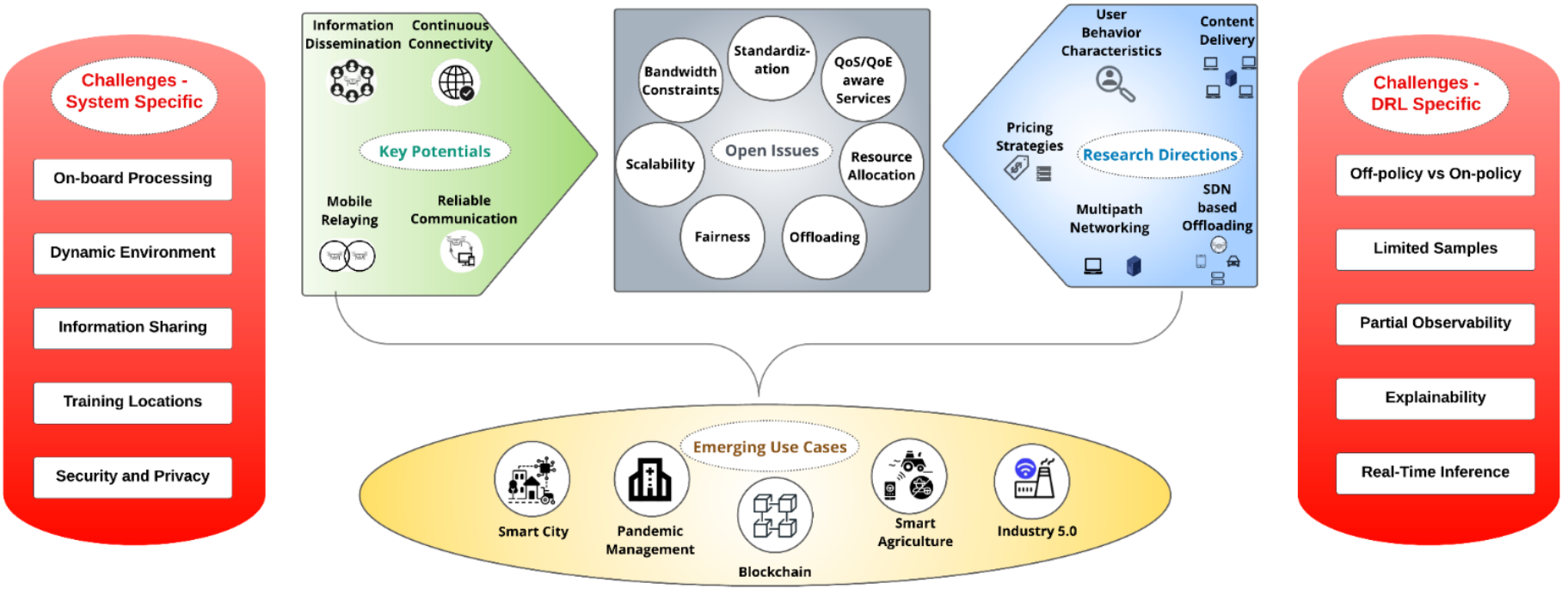
Computation offloading using MADDRL

- In order to develop an efficient computation offloading policy, our approach utilizes the three learning frameworks of MADDRL including CTDE, IL and NA that enables users to make decentralized computation offloading decisions.
- Our proposed methods consistently outperform the baseline methods in minimizing the cost defined as weighted sum of delay and energy consumption.



14. Nida Fatima, Paresh Saxena, and Giovanni Giambene. (2024). Computation Offloading in NTN-empowered MEC using Multi-Agent Distributed Deep Reinforcement Learning. In 2024 IEEE Global Communications Conference (GLOBECOM), Accepted.
15. Nida Fatima, Paresh Saxena, and Giovanni Giambene. (2024). Policy Gradient-based MADDRL Approach for Computation Offloading in NTN-empowered MEC. In IEEE International Conference on Cloud Computing Technology and Science (CLOUDCOM), Accepted.
16. Nida Fatima, Paresh Saxena, and Giovanni Giambene. (2024). Computation Offloading in NTN-empowered MEC: A Partially Observable Multi-Agent Distributed Deep Reinforcement Learning Approach. Submitted to Ad Hoc Networks.

Challenges and Opportunities



17. Harsha Varun Marisetty, Nida Fatima, Manik Gupta, and Paresh Saxena. (2024). Relationship between resource scheduling and distributed learning in IoT edge computing-An insight into complementary aspects, existing research and future directions. Internet of Things, pp. 101375. DOI: https://doi.org/10.1016/j.iot.2024.101375

Wireless World Research Forum (WWRF53)
18th Feb to 20th Feb 2025, BITS Pilani, Hyderabad

https://www.bits-pilani.ac.in/wwrf53/

THANK YOU

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