Title: **Improved Resource Management and Link Reliability in Future Satellite Communication Networks**

Context:

With the rise of Internet-of-Things (IoT) applications and the need for massive connectivity, future 6G networks should meet the demands for the global access to high-speed Internet [1]. One of the envisaged solutions consists in deploying non-terrestrial networks such as networks of satellites or microsatellites in the low Earth orbit (LEO). Such satellites have a much lower manufacturing and launch costs than the traditional satellites, such as those placed in the geostationary orbit. Such very high-throughput satellite (VHTS) networks, will be able to meet the substantial data traffic requirements [1,2]. The specificity of these satellites (or microsatellites) is that they have limited capacities and resources (energy, computing, etc.). However, they are more flexible in terms of resource management, such as power and bandwidth allocation. On the other hand, another particularity of such networks is the irregular distribution of users (on the Earth) and the variability of connections and, therefore, the data traffic over time. This calls for the design of efficient architectures so as to allocate the necessary resources in a flexible manner and according to the requested traffic [3].

Research project:

The above-mentioned issues motivate the development of automated resource allocation strategies through cognition and machine learning to exploit the flexibility of these satellite networks in order to increase their capacity and to improve the link reliability.

An promising solution is to deploy satellites using multiple beams with the possibility of dynamic resource management, which can potentially increase the complexity of such VHTS networks significantly.

This research project will consider the use of laser links (rather than radiofrequency links), which offer the advantages of high energy efficiency, robustness against electromagnetic interference, and lower complexity for realizing signal transmission with multiple beams [4,5].

In a first step, the proposed work concerns channel modeling for satellite-to-Earth and inter-satellite optical communication links. This will be mainly based on using MODTRAN simulation tool in collaboration with the Li-Fi Research Center in the University of Edinburgh, to analyze the atmospheric effects for different network topologies and different geometric parameters.

In a second step, the work will focus on the development of deep learning methods to optimize the resource allocation in a dense network of small satellites [6]. Implementing this automation, enhanced by cognition and machine learning, will help optimize data transmission, reduce operating costs, and manage system complexity [7,8]. Additionally, due to a high level of distortion of the optical signal, in particular, in satellite-to-Earth links, appropriate learning strategies with reasonable implementation complexity will be developed for signal detection at the receiver [9,10].

Collaborations :

This project will be carried out in close collaboration with the “LiFi Research Center” of the University of Edinburgh (UK), the CNES, and “Mobile Communication Systems lab” of Aalto University (Finland).

References:

[1] E. Yaacoub, M.-S. Alouini, "A Key 6G Challenge and Opportunity - Connecting the Base of the Pyramid: A Survey on Rural Connectivity," *Proceedings IEEE*, vol. 108, Apr. 2020

[2] N. U. L. Hassan et al., "Dense Small Satellite Networks for Modern Terrestrial Communication Systems: Benefits, Infrastructure, and Technologies," in *IEEE Wireless Communications*, vol. 27, no. 5, pp. 96-103, October 2020

[3] B. Deng et al., "The Next Generation Heterogeneous Satellite Communication Networks: Integration of Resource Management and Deep Reinforcement Learning," in *IEEE Wireless Communications*, vol. 27, no. 2, pp. 105-111, April 2020

[4] M.A. Khalighi, M. Uysal, “Survey on Free Space Optical Communication: A Communication Theory Perspective,” *IEEE Communications Surveys & Tutorials*, vol. 16, no.8, pp. 2231–2258, Nov. 2014

[5] E. Illi et al., "A PHY Layer Security Analysis of a Hybrid High Throughput Satellite with an Optical Feeder Link," in *IEEE Open Journal of the Communications Society*, vol. 1, pp. 713-731, 2020

[6] X. Hu et al., "Multi-Agent Deep Reinforcement Learning-Based Flexible Satellite Payload for Mobile Terminals," in *IEEE Transactions on Vehicular Technology*, vol. 69, no. 9, pp. 9849-9865, Sept. 2020

[7] P. V. R. Ferreira et al., "Reinforcement Learning for Satellite Communications: From LEO to Deep Space Operations," in *IEEE Communications Magazine*, vol. 57, no. 5, pp. 70-75, May 2019

[8] F. G. Ortiz-Gomez et al., "Convolutional Neural Networks for Flexible Payload Management in VHTS Systems," in *IEEE Systems Journal*, 2021 (in press)

[9] E. Zedini, A. Kammoun, M. -S. Alouini, "Performance of Multibeam Very High Throughput Satellite Systems Based on FSO Feeder Links With HPA Nonlinearity," in *IEEE Transactions on Wireless Communications*, vol. 19, no. 9, pp. 5908-5923, Sept. 2020

[10] N. A. Amran et al., "Deep Learning Based Signal Detection for OFDM VLC Systems," *2020 IEEE International Conference on Communications Workshops (ICC Workshops)*, Dublin, Ireland, 2020