6G-RIC Research and Innovation Cluster

GEFÖRDERT VOM Bundesministerium für Bildung und Forschung

# Simultaneous Computation and Communication over MAC

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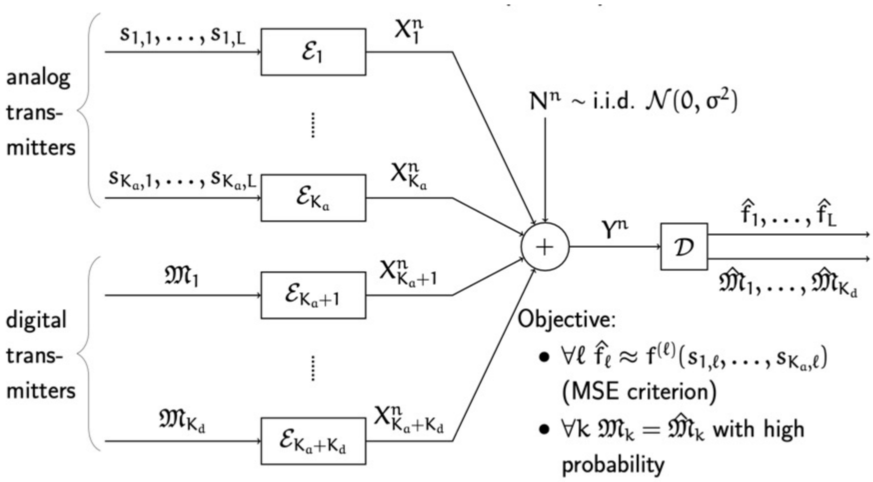
**How to embed analog distributed function computation (Over-the-Air computation) into communication systems simultaneously with traditional digital communication? What are the resulting trade-offs between the compute and digital communication rates? How to design practical coding/preprocessing schemes that achieve the goal of simultaneous distributed analog function computation and digital transmission?**




*We investigate the simultaneous transmission of digital messages and distributed computation/approximation, called Over-the-Air computation, from a large number of digital and analog transmitters to a single receiver. This communication setup enables the integration of several important tasks (like physical layer network coding, distributed sensing and control, as well as distributed optimization for federated learning) as a basic functionality of wireless communication system. These network functionalities are embedded into the communication system by a suitable choice of the analog functions that are being computed in parallel to digital communication.*

## KEY FINDINGS

We study communication over a Gaussian multiple access channel with two types of transmitters: Digital transmitters hold a message from a discrete set that needs to be communicated to the receiver. Analog transmitters hold sequences of analog values, and some function of these distributed values (but not the values themselves) need to be conveyed to the receiver. For the digital messages, it is required that they can be decoded error free at the receiver with high probability while the recovered analog function values have to satisfy a fidelity criterion such as an upper bound on minimum square error (MSE) or a certain maximum error with a given confidence. For the case in which the computed function for the analog transmitters is a sum of values in [-1,1] we derive inner and outer bounds for the tradeoff of digital and analog rates of communication under peak and average power constraints for digital transmitters and a peak power constraint for analog transmitters. We then extend the achievability part of our result to a larger class of functions that includes all linear, but also many practically relevant non-linear functions.

The scheme developed for the achievability result is modular and constructive: traditional practical codes (e.g., polar codes, LDPC, SPARC etc.) for digital communication are altered in such a way by a linear pre- and post-processing of low computational cost that the resulting code for digital communication can be used for reliable simultaneous digital communication and analog computation.

*Frey, I. Bjelakovic, M. C. Gastpar and J. Zhu, "Simultaneous Computation and Communication over MAC," 2024 IEEE International Symposium on Information Theory (ISIT), Athens, Greece, 2024, pp. 3350-3355, doi: 10.1109/ISIT57864.2024.10619540.*