

## ABSTRACT:

### **Reconfigurable Intelligent Surfaces (RIS) for Communication, Sensing, and Localisation**

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Reconfigurable Intelligent Surfaces (RIS) have emerged as a transformative technology for next-generation wireless networks, enabling precise control of electromagnetic waves to enhance communication, sensing, and localisation. RIS leverages programmable metasurfaces composed of sub-wavelength reflective elements to dynamically manipulate the amplitude, phase, and polarization of incident waves. This capability supports diverse applications in 6G scenarios, including high-speed data transmission, real-time health monitoring, and indoor localisation. In communication, RIS improves energy efficiency and signal coverage, particularly in Non-Line-of-Sight (NLoS) environments. It achieves efficient beamforming with minimal power consumption and low hardware complexity. For sensing applications, RIS enables high-accuracy vital sign detection, including real-time heartbeat and respiration monitoring in NLoS conditions, overcoming limitations of conventional RF sensing technologies. Using a novel RIS prototype with 4096 elements, recent studies demonstrated its ability to enhance signal-to-noise ratios and classify micro-activities with unprecedented precision [1].

For localisation, RIS enhances the performance of machine-learning-based indoor positioning systems by reshaping radio wave propagation and reducing multipath fading effects. Experimental results indicate that RIS-assisted localisation achieves accuracy exceeding 82% by optimizing channel state information (CSI) and received signal strength indicators (RSSI) through intelligent RIS configurations [2]. The technology supports both active and passive localisation methods, making it ideal for complex, dynamic environments. RIS holds immense potential in integrated sensing and communication (ISAC) systems, paving the way for innovative solutions in smart homes, healthcare, and urban environments. By addressing challenges such as NLoS coverage, hardware constraints, and energy efficiency, RIS is poised to play a critical role in realising the vision of ubiquitous, intelligent, and sustainable wireless networks.

[1] J.u.R. Kazim, A. Tahir, J. Rains, T.J. Cui, A. Jabbar, M.A. Jamshed, M. Ur-Rehman, A. Alomainy, M.A. Imran, and Q.H. Abbasi, *Adv. Intell. Syst.*, 5, 2300007 (2023).

[2] S.T. Shah, M.A. Shawky, J.u.R. Kazim, A. Taha, S. Ansari, S.F. Hasan, M.A. Imran, and Q.H. Abbasi, Communications Engineering, 3, 66 (2024).