# STAR-RIS Assisted Integrated Sensing and Communication (ISAC): A Brief Survey

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Abstract

This paper provides a comprehensive survey of the recent advancements in integrated sensing and communication (ISAC) facilitated by simultaneously transmitting and reflecting reconfigurable intelligent surfaces (STAR-RIS). We focus on key contributions, methodologies, and optimization techniques in STAR-RIS assisted ISAC systems, highlighting their impact on enhancing wireless communication efficiency and capability.

## Ⅰ. Introduction

The exponential growth in demand for higher data rates and lower latency in wireless communications has driven the exploration of innovative technologies. Integrated sensing and communication (ISAC) emerges as a pivotal technology, promising efficient spectrum utilization and enhanced environmental awareness. The advent of simultaneously transmitting and reflecting reconfigurable intelligent surfaces (STAR-RIS), which operate in three modes: energy splitting (ES), time switching (TS), mode switching (MS) [1], guarantees 360-degree coverage. The combination of ISAC with STAR-RIS has further catalyzed advancements by improving signal quality and coverage, reducing power consumption, and enabling more robust and adaptable networks. This paper reviews the convergence of these technologies, focusing on their integration, benefits, challenges, and prospects for future research.

## II. Integration of ISAC with STAR-RIS

The integration of ISAC with STAR-RIS provides significant flexibility by enabling dynamic adjustments of the system to immediate environmental and traffic conditions. Fig. 1 shows an example of STAR-RIS assisted ISAC system, where a sensing target and communication devices are located in separate spaces. The study in [2] demonstrated how STAR-RIS can divide the space around it into distinct zones for sensing-only and communication-only purposes, effectively enhancing the performance in these distinct domains using ES mode. It suggested that, compared with employing more sensor elements, installing more passive elements is more efficient in practice to enhance performance and reduce cost. The application of STAR-RIS in TS mode was studied in [3], the development of a bi-directional sensing and STAR-RIS

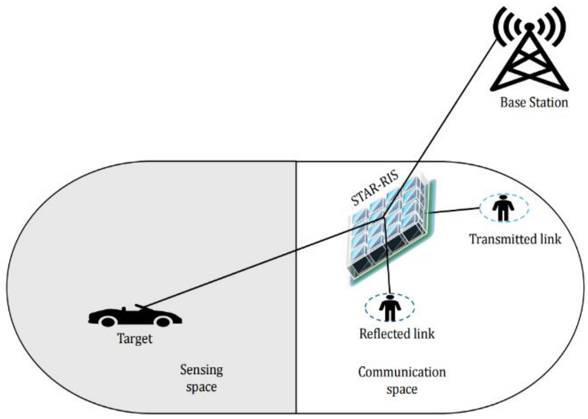


Fig. 1 STAR-RIS assisted ISAC system.

architecture, enabling comprehensive simultaneous transmission and reflection in response to space utilization for both communication and sensing in a sequential manner. This framework also includes the optimization of the Cramér-Rao Bound (CRB) for pinpointing the two-dimensional direction-of-arrival of sensing targets.

In [4], an active STAR-RIS aided ISAC system was described where a dual-function base station (DFBS) equipped with multiple antennas leverages an active STAR-RIS to deliver communication services to multiple users while simultaneously conducting target sensing. This integration allows the optimization of beamforming at both the DFBS and STAR-RIS across various operational modes to maximize communication rates while adhering to the minimum radar signal-to-noise ratio (SNR) requirements, the operational limits of active STAR-RIS, and overall power constraints. In a further development, STAR-RIS-assisted ISAC using the ES mode was considered in [5] to enhance the long-term secrecy rate of legitimate users by utilizing deep reinforcement learning algorithms such as deep deterministic policy gradient and soft actor critic.

For STAR-RIS aided ISAC combined with non-orthogonal multiple access (NOMA), the fairness was examined in [6] and the secrecy rate was maximzied in [7]. The study in [6] focuses on maximizing fairness between communication and sensing performances, using sequential convex approximation (SCA) and semidefinite programming (SDP) methods to fine-tune the transmit beamforming and reflection coefficients of STAR-RIS. In the meantime, [7] explored how to maximize the sum secrecy rate by concurrently optimizing the transmit beamforming, artificial jamming, and passive transmission and reflection beamformings of STAR-RIS using the ES mode, ensuring sufficient beampattern gain for target requirements. A matching error minimization problem was addressed to the STAR-RIS aided NOMA with the TS protocol [8] for which BS active beamforming and STAR-RIS passive beamforming along with power and time allocation factors was optimized to meet minimum communication rate requirements. Lastly, Xue et al. scrutinized the coordination of user power allocation, and active and passive beamforming designs for STAR-RIS aided ISAC with NOMA and ES mode to fulfill both communication and radio sensing needs [9]. In a subsequent journal version [9], a non-convex problem focusing on minimum beampattern gain maximization in a STAR-RIS assisted cluster-based NOMA transmission was tackled using a block coordinate descent (BCD) based integral matrix algorithm to achieve a suboptimal solution, with semidefinite relaxation and SCA optimizing the coupled variables [10].

## III. Challenges and Future Directions

Despite promising advancements, several challenges remain. These include hardware limitations, such as the design and fabrication of cost-effective and efficient STAR-RIS panels, and software challenges, such as development of algorithms that can dynamically adapt to changing environmental conditions and user demands. Future research may focus on machine learning approaches for better prediction and adaptation strategies, security aspects of ISAC systems, and cross-layer design optimizations to fully exploit the potential of STAR-RIS in next-generation wireless networks.

## IV. Conclusion

This survey highlights the important role of STAR-RIS in developing efficient ISAC systems. Significant progress has been made, but further research and innovation are needed to address current challenges and fully realize the potential of these technologies. Ongoing efforts in research and collaboration will be key to enhancing and integrating sensing and communication in future wireless networks.


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