Reconfigurable Intelligent Surfaces: Standardization and Testbed Development in India

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Introduction

RIS are planar structures comprising programmable meta-materials that manipulate electromagnetic waves to enhance wireless communication.

Proposed advantages include improved coverage in non-line-of-sight (NLOS) scenarios, enhanced beamforming for higher data rates, and cost-effective deployment. However, challenges such as deployment scalability, accurate channel estimation, and integration with existing networks must be addressed for RIS to achieve its full potential.

TSDSI has recently published a standard on Methods and Interface Design for RIS-assisted Communication Systems [1] that specifies the architecture, interface and mechanisms in a RIS-assisted communication system. This standard is a first step to define the methods and procedures involved in the implementation of RIS. It will be followed by other standards on RIS on which work has already begun in TSDSI.

Recent reports from ETSI ISG [2] and RISTA [3] highlight the growing attention being given to utilizing Reconfigurable Intelligent Surfaces (RIS) to assist radio communications, especially for consumer applications. Emerging research suggests that RIS holds significant potential for advancing next-generation wireless networks. Although several technical challenges remain, Industry seems convinced about the potential practical promise of this technology and has started making standardization efforts in parallel.

The academic and research communities across the world are also involved in projects aimed at better understanding and utilization of this technology. This is also emphasized in the World Economic Forum report placing RIS as third in the list of top 10 technologies of 2024, see [4].

This article gives a brief overview of the general architecture and interface specified in the TSDSI Standard [1], and describes key features of an open RIS test bed that has been developed under the aegis of the COMET foundation and is based on the TSDSI Standard.

General Architecture

The initial approach adopted by TSDSI has been to provide a communication technology-agnostic generic interface (messages) towards the RIS hardware that can be translated to appropriate electrical control of RIS elements to achieve the desired overall RF behavior. This architecture, derived from [1], is shown in Figure 1.

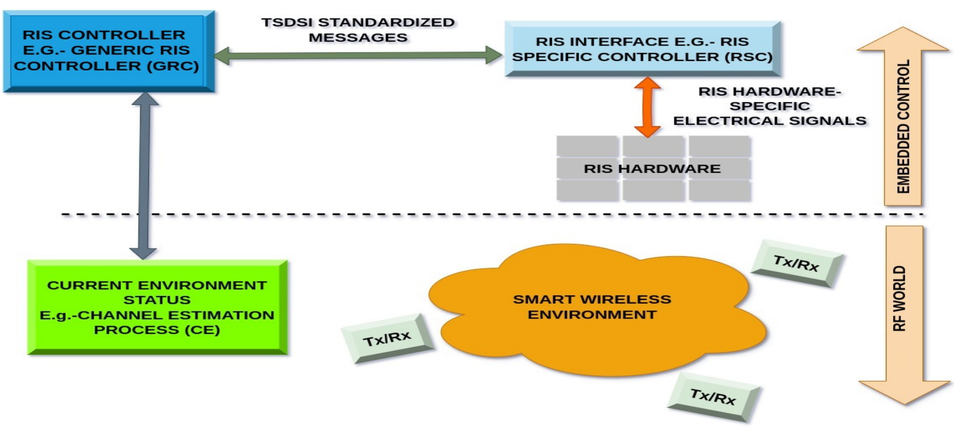

Figure 1: **The generic architecture of RIS-based communication.**

TSDSI RIS Standard Interface and It's Usage

The interface consists of multiple messages that enable initialization, capability queries, configuration updates, and response to queries. An example of the way in which these messages can be used in a practical system [5] is depicted in Figure 2, as deployed in the testbed described in the next section.

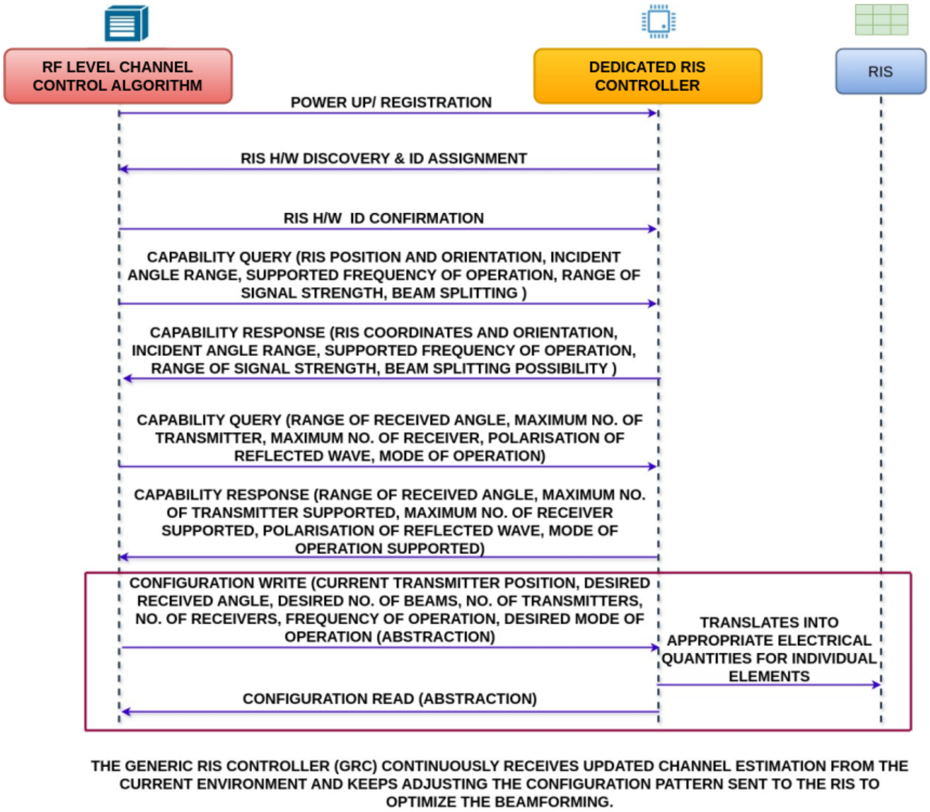

Figure 2: **Standardized message flow between RF-level channel control and RIS Controller**

The interface between the RF-level channel control (algorithm) RIS Controller and the RIS hardware specific controller, as shown in Figure 2, are crucial to ensure interoperability and vendor independence in RIS-based communication systems. This interface serves as an abstraction that encapsulates parameters subject to variation, such as vendor-specific, technology-specific, and operational requirements. These parameters may include transmitter position, desired received angle, beam count, number of transmitters, number of receivers, operating frequency, and mode of operation. Upon system startup, the RF-level channel control identifies and registers the Dedicated RIS Controller for local network service discovery. Following this, the RF-level channel control sends capability query messages to ascertain the Dedicated RIS Controller's operational parameters, such as RIS position, orientation, incident and reflection angle ranges, and beamforming capabilities. The Dedicated RIS Controller responds with detailed specifications, enabling the RF-level channel control to determine optimal configurations. Subsequently, the RF-level channel control issues configuration commands to the Dedicated RIS Controller, which translate them into specific electrical instructions for the RIS elements, ensuring accurate beamforming. This modular interaction facilitates dynamic adjustments, such as altering the RIS azimuth for maximum received power, as demonstrated in experimental scenarios.

The standardization of the interactions ensures consistent RF-level channel control -Dedicated RIS Controller communication, regardless of the underlying RIS architecture/hardware. This aspect is pivotal for enabling diverse RIS designs to coexist within a unified framework, fostering flexibility and scalability. Additionally, this structure supports advanced capabilities like autonomous mode operation, where the RF-level channel control iteratively evaluates beamforming angles to maximize throughput without manual intervention. By adopting such a standardized interface, TSDSI sets a foundation for integrating RIS into existing and future wireless communication standards, paving the way for enhanced network performance and efficient resource utilization.

Open RIS Testbed

The architecture of the TSDSI standard-compliant open RIS testbed, offering a plug-and-play approach to incorporate/change the various entities involved in end-to-end RIS-assisted communication system is detailed in [5]. This standard, adopted under the collaborative project sponsored by the COMET Foundation, has led to the development of an open-access testbed created through the joint efforts of IIT Delhi, IIT Bhilai, IIT Jodhpur, IIT Dhanbad, IIT Indore, IIIT Bangalore, and IIIT Naya Raipur. TSDSI specifications [1], ensure a coherent technology by specifying the end to end architecture, interface and mechanisms involved in various stages of development and implementation of RIS in a RIS-assisted communication system. The technical details of the open-source testbed setup are available in [5].

The setup, involves a dedicated controller to control the RIS configuration. It includes modules that monitor and estimate the RIS assisted channel. The system offers flexibility, allowing various researchers to integrate their algorithms through a plug-and-play method, using a channel estimation tailored to their specific communication technology. An RF-level channel control directs the dedicated controller, through TSDSI 5003 interface, to translate TSDSI standard instructions to electrical signals. The setup also includes a calibration tool for RIS manufacturers. Researchers working on generic controller can integrate their algorithm with the system while using standard interface to interact with the CE and Dedicated RIS Controller entities.

A detailed design and application development document is available at [6]. The modularity of RF-level channel control and Dedicated RIS Controller communication, using standardized APIs, supports integrating various RIS designs, fostering innovation and practical deployment scenarios for future wireless networks.

Conclusion

The TSDSI standards-driven approach for a typical RIS-enabled communication indicates the importance of modular, scalable interface for future wireless networks. This work lays the foundation for integrating RIS into global wireless standards, ensuring enhanced performance and resource utilization.

The future of RIS standardization in India is closely aligned with the vision outlined in the TSDSI Roadmap 3.0 [7]. With a focus on 6G/5G enhancements, rural coverage, and integration of AI/ML, RIS technology is poised to revolutionize wireless networks. The standardization process will emphasize system requirements, performance metrics, and guidelines for RIS-aided networks, along with addressing hardware design, software control, and integration with technologies like AI/ML and THz communication. Interoperability, collaboration between standardization bodies, and the development of testing protocols will be critical to ensuring the seamless integration of RIS into future network architectures.

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