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RIS: A Key Building Block for 6G

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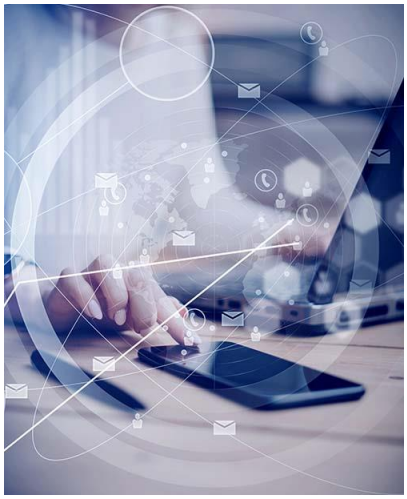

Wireless communications, or the transmission and reception of radio waves, have revolutionized the world, to the extent that it is nearly impossible to envision our day-to-day lives without them. To enable transfer of information between a transmitter and a receiver over the air, one must deal with the uncertain and determinantal impacts the wireless channel has over radio signals. Today's wireless systems are built around the principles of wireless channel adaptation, meaning sophisticated design mechanisms at the transmitter, receiver, or both that attempt to deal with the wireless channel impairments. Following several decades of work, wireless systems such as 5G, and technologies therein, such as massive MIMO, can deliver unprecedented performance.

Despite the great successes to date, the rapid changes in traffic demand require innovative sustainable wireless solutions beyond deploying traditional network infrastructure, which comes at a high cost to design, implement, deploy, and operate. An emerging concept in this direction that has received a lot of attention in the wireless community is "smart radio environments," which involve going beyond adaptive wireless communications to shaping and controlling the radio environment in a goal-oriented way. The main technology to achieve this is known as reconfigurable intelligent surface (RIS), which also goes by several other names such as reflecting intelligent surfaces, smart repeaters, and holographic radios.

Understanding RIS

RIS is a completely new type of network node, different from conventional fully stacked cells, relays, and repeaters. It has a conformal structure engineered to have properties that enable the network to dynamically shape and control the radio waves impinging on the surface. RIS can be

made of a large array of passive scattering elements called unit cells, which can be configured by the network to achieve desired signal reflections, refractions, focusing, collimation, modulation, and their combinations.

RIS can be implemented using mostly passive components and as such the cost to produce, deploy, and operate RIS may be lower compared to fully stacked cells, relays, and repeaters. These smart radio surfaces may take any shape or be integrated onto objects, providing ease and flexibility for deployment. RIS can be targeted for both indoor and outdoor usage, including at offices, airports, and shopping centers, as well as on lamp posts and advertising billboards. RIS uses mostly passive components, and therefore it may result in low energy consumption, making it a sustainable, environmentally friendly technology solution. RIS can be configured to operate at any part of the radio spectrum, including frequencies from sub-6 GHz to THz. It is anticipated tools from artificial intelligence and machine learning (AI/ML) can serve as key enabling tools for RIS operation and optimization.

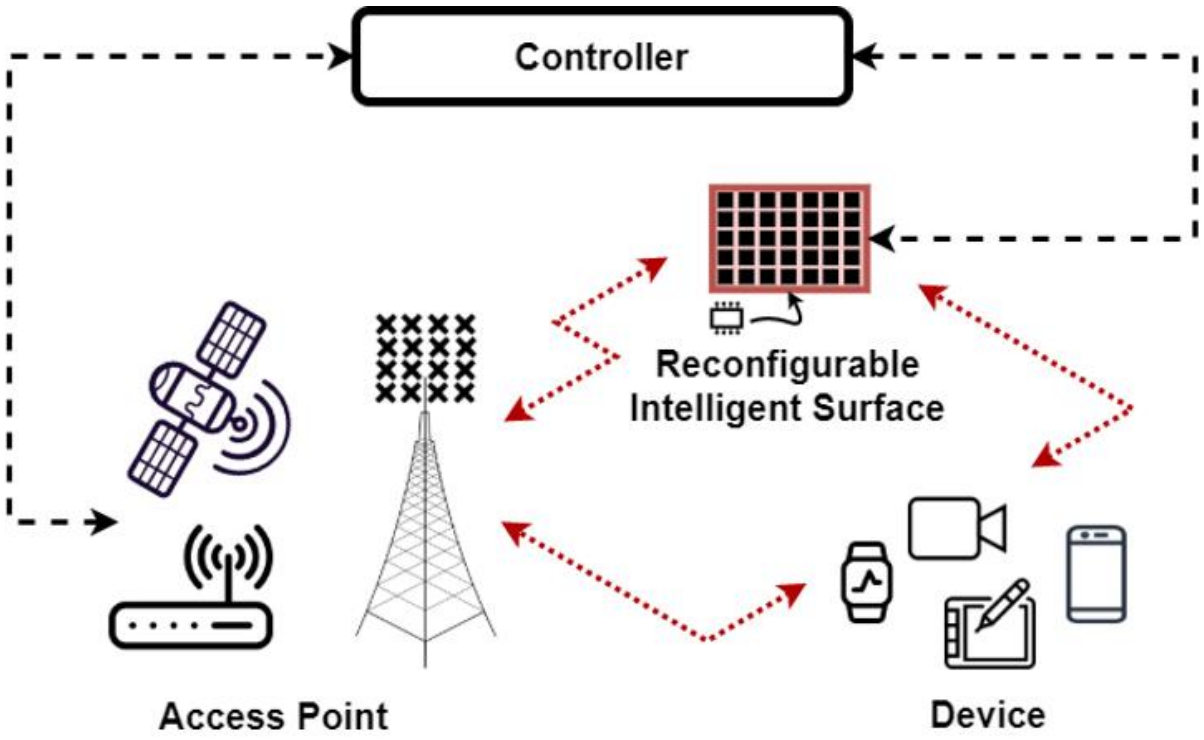

Figure 1. Illustrative diagram of RIS, a new type of system node with smart radio surface technology with a response can be adapted to the status of the propagation environment through control signalling.
click to enlarge

For these reasons, RIS is envisioned as a promising candidate enabling future wireless technology for the control of the radio signals between a transmitter and a receiver in a dynamic and goal-oriented way. It has the potential to change the wireless environment from a passive to an intelligent actor. This has motivated a host of potential new use cases targeted at improving various systems' KPIs, such as capacity, coverage, positioning, sustainability, and security. In addition to improved performance, RIS could enable new wireless applications such as sensing,

localization, and ambient backscattering. Because of these benefits and possibilities, RIS is expected to serve as a key technology in future wireless systems, including 6G.

An illustrative diagram of RIS is provided in Figure 1 (see page one). It depicts RIS as a new system node dynamically configured by the system controller, which turns the wireless environment from a passive to an intelligent actor such that the channel becomes programmable. A comparison of RIS and its unique characteristics against other wireless technology concepts is provided in Figure 2. RIS will challenge basic wireless system design paradigms, creating innovation opportunities that will progressively impact the evolution of wireless system architecture, access technologies, and networking protocols.

Global RIS research projects

RIS has attracted a lot of global attention in the research community, especially in Europe. There are already several European collaborative research and innovation projects working on this topic such as AIMM, ARIADNE, DAEMON, HEXA-X, and RISE-6G, to name a few. The members of these projects include a wide range of network operators, telecom equipment vendors, and research institutes.

In addition, the Institute of Electrical and Electronics Engineers (IEEE) Communication Society has launched two special interest groups and one emerging technology initiative on RIS; these are RISE SIG, REFLECTIONS SIG, and RIS ETI. There have also been prototyping and testing results for RIS, including metasurface reflective arrays demonstrations, for example by NTT DoCoMo, Orange, MIT, and the University of Surrey.

Concept	Characteristics	Key Differences over RIS
Reconfigurable Intelligent Surface	Intelligent radio surface whose response can be reconfigured using control signaling	–
Surface	Passive surface that follows Snell's law (for example a metallic sheet)	Fully passive
Intelligent Surface	Surface that can be appropriately engineered/designed to go beyond Snell's law	Not reconfigurable
Repeater	Non-regenerative relay which can amplify and forward RF signals	Requires some active components, but with lower control overhead
Relay	Regenerative relays which can decode and forward RF signals	Requires significant active components and digital signal processing
Massive MIMO	Antenna-integrated radio, typically comprising many transceiver chains	Fully active, full-stack cell

Figure 2. Unique characteristics of RIS against other wireless technology concepts
click to enlarge

RIS technology is supported as a key technology trend in the International Telecommunication Union Radiocommunication Sector (ITU-R) IMT-2030 Future Technology Trends report. There

have also been early attempts recently to bring RIS for exploratory studies in standards development organizations including 3GPP (3rd Generation Partnership Project) and IEEE.

While extensive research efforts are ongoing on the topic, global standardization of RIS is still at its very early stages. There are many technical challenges that need to be adequately addressed before RIS can be adopted into future standards, toward eventual commercialization of the technology.

ETSI, which produces globally applicable standards for ICT, has launched a new Industry Specification Group on Reconfigurable Intelligent Surfaces (ISG RIS). The group has been created to review and establish global standardization for RIS technology. This initiative was formed to streamline pre-standards research efforts on RIS technology across various EU and UK collaborative projects, extended with relevant global initiatives toward paving the way for future standardization of the technology.

ETSI ISG RIS, which launched in September 2021 with a duration of two years, will identify and describe RIS-related use cases and deployment scenarios, specify derived requirements, and identify technology challenges in several areas, including fixed and mobile wireless access, fronthaul and backhaul, sensing and positioning, energy and electromagnetic field (EMF) exposure limits, security, and privacy. The group will clearly document a networking e2e reference architecture including RIS elements, describe RIS-based specific deployment practices and guidelines, provide a gap analysis for RIS microelectronics and enabling technologies, and make proofs of concepts. The ISG activities and deliverables will be complementary to existing ETSI work and relationships with other ETSI bodies, and the wider industry will be established to avoid duplication, maximize synergies and act to ensure broad industry adoption of RIS, a key technology trend for future wireless systems.

Further information on the ISG RIS scope, work program, and deliverables can be accessed through the ISG RIS Portal.