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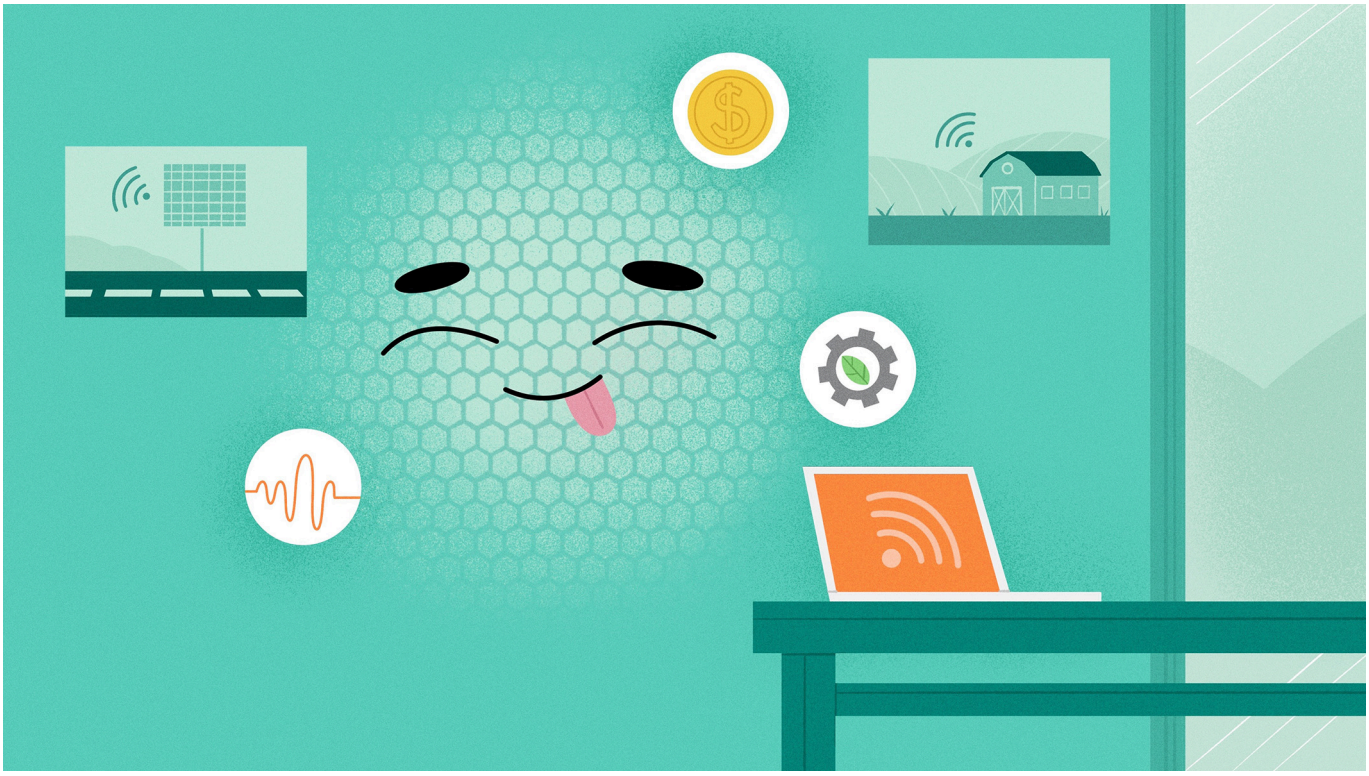

REVOLUTIONIZING WIRELESS NETWORKS WITH INTELLIGENT SURFACES

Mohamed-Slim Alouini [1*], ***Marco Di Renzo*** [2] ***and Javier Garcia Martinez*** [3]

[1] *UNESCO Chair on Education to Connect the Unconnected King Abdullah University of Science and Technology (KAUST), Thuwal, Makkah Province, Saudi Arabia*

[2] *L2S-CNRS-CentraleSupélec, France & King's College London, London, United Kingdom*

[3] *Department of Inorganic Chemistry, Molecular Nanotechnology Lab, University of Alicante, Alicante, Spain*

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Reconfigurable intelligent surfaces (RIS) are a new technology that can improve wireless networks by turning ordinary surfaces, like walls or ceilings, into tools for communication. These "smart mirrors" reflect and adjust signals, making networks faster, more reliable, and more energy efficient. RIS are already being tested to boost Wi-Fi in smart homes, improve connectivity in smart factories to ensure smooth operations, and help devices like fitness trackers and farm sensors communicate better and last longer. While RIS have great potential, there are challenges to solve. The materials and systems needed for RIS are expensive, and clear rules are needed to ensure they work safely without interfering with other devices. Despite these hurdles, by making networks smarter and greener, RIS could create

a future where wireless communication is faster, more efficient, and better for the planet.

THE WORLD NEEDS GREENER NETWORKS

Have you ever wondered how the devices we use every day, like smartphones, laptops, and smart home devices, work? They all rely on the internet—and behind the internet are networks. Networks are systems that move information between devices, helping billions of people stay connected through video calls, online games, and streaming. But as more people use the internet every day, these networks need to be faster, more reliable, and better for the environment. Right now, they use a lot of energy, which increases carbon emissions and harms the planet. With new technologies like 6G networks on the way, the challenge is to meet our growing internet demands without making climate change a lot worse.

What if our wireless networks could work smarter, not harder? Traditional wireless systems must deliver strong, consistent signals from communication towers to our devices—often through walls, buildings, or other obstacles that weaken the connection. To fix this, wireless networks rely on powerful transmitters—devices that help send powerful signals over long distances—but these use a lot of energy. Instead, imagine if a building's walls or ceilings could become active parts of the network, directing wireless signals in specific directions to make sure they reach devices efficiently. This could boost connectivity, save energy, and protect the environment.

RECONFIGURABLE INTELLIGENT SURFACES

Smart surfaces that act like mirrors, adjusting themselves to improve wireless signals, saving energy, and making networks work better.

METAMATERIALS

Special materials designed at a tiny scale using structures called unit cells. These materials can do things natural materials cannot, like bending wireless signals around obstacles.

ELECTROMAGNETIC WAVES

Invisible waves that carry energy, like light, radio, or Wi-Fi signals, allowing devices to send and receive information.

EMERGING TECHNOLOGY: RECONFIGURABLE INTELLIGENT SURFACES

Reconfigurable intelligent surfaces (RIS) are advanced technologies that can improve wireless signals by turning ordinary surfaces, like walls or ceilings, into tools for wireless communication [1]. "Reconfigurable" means the surface can be adjusted or changed as needed to direct signals more efficiently, and "intelligent" refers to the system's ability to analyze its environment and make decisions in real time. You can think of RIS as "smart mirrors" that reflect signals exactly where they are needed, like bouncing a beam of light to illuminate a dark corner.

These smart surfaces are made of **metamaterials**—unique materials designed at the microscopic level to do things natural materials cannot. Tiny structures that make up the metamaterials, called unit cells, interact with **electromagnetic waves** (like Wi-Fi or phone signals) to adjust the signal's direction or strength. Unlike regular materials that simply absorb or reflect signals without changing them, metamaterials can bend waves around obstacles or focus them like a lens. For

instance, in a crowded office building where signals have trouble reaching all areas, RIS on the walls could redirect Wi-Fi signals around barriers, to ensure that everyone in the building has a strong connection.

RIS rely on **smart algorithms** and **signal processing** to figure out how to adjust the signal. Smart algorithms act like the "brains" of the system, calculating the best way to handle wireless signals. Signal processing analyzes data about the signals, such as how many people are connected or whether walls or obstacles are blocking the signal. Using this real-time information, an RIS can adjust itself to strengthen the signal, send it around obstacles, or focus it in the right direction.

This technology could save energy by reducing the need for powerful transmitters, which use a lot of electricity. By making signals more precise, RIS offer a greener, more efficient way to build wireless networks for the future [2, 3].

SMART ALGORITHMS

Computer programs that act like "brains", using calculations and rules to make decisions, like how to direct wireless signals.

SIGNAL PROCESSING

Analyzing waves of data, such as internet or phone signals, to understand how they are behaving and improve their performance.

TECH TO THE RESCUE

RIS are being tested in several industries to see if they can solve real-world problems (Figure 1) [4]. One important use is in the **internet of things (IoT)**, a network of everyday objects—like smart home devices, wearable fitness trackers, or sensors in farmers' fields—that connect to the internet and "talk" to each other. These devices can make life easier and safer by sharing information. For example, a smart thermostat might adjust your home's temperature based on data from a weather app, or a fitness tracker on your watch could send your step count to a health app on your phone. IoT devices often run on small batteries and need strong, reliable wireless signals to work well. RIS can reflect signals directly to these devices, reducing energy use and helping batteries last longer.

INTERNET OF THINGS

A network of everyday objects, like smart home devices or fitness trackers, that are connected to the internet and share information.

In a smart home, RIS panels on walls or ceilings could boost Wi-Fi signals so devices in every room have a strong connection. On a farm, sensors might track soil moisture and send the data to a farmer's phone. RIS panels on barns or towers could ensure these sensors communicate over long distances without draining their batteries. RIS also show promise is in **smart factories**, where machines and sensors constantly share data to keep operations running smoothly. Factories often have lots of metal machinery and other obstacles that can block wireless signals. RIS panels installed on walls, ceilings, or equipment could redirect signals around obstacles, ensuring that all machines and sensors stay connected. For example, a RIS-enhanced factory might use robotic arms to assemble products on one side of the building, while sensors monitor equipment performance on the other side. Instead of signals getting lost in the maze of machinery, RIS could bounce them efficiently to where they are needed, reducing downtime and improving productivity.

SMART FACTORIES

Factories that use advanced technology, like sensors and robots, to share information, improve efficiency, and reduce waste.

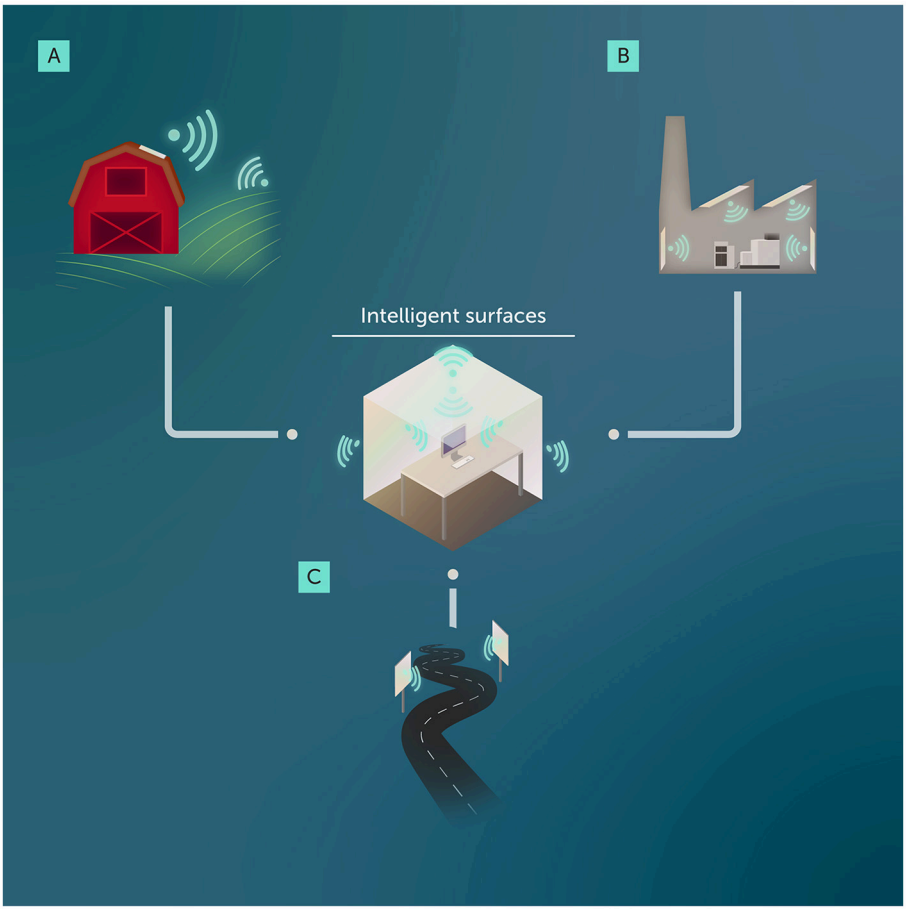

Figure 1

RIS can improve wireless communication by turning ordinary surfaces into part of a wireless network. **(A)** RIS panels on barns or other farm buildings could communicate with sensors in farmers' fields to track soil or crop conditions. **(B)** In smart factories, RIS could help wireless signals get around bulky equipment and other obstacles, ensuring that factories run smoothly by keeping machines and sensors connected. **(C)** RIS panels on road signs could communicate with passing cars, providing drivers with updates on road conditions and helping to prevent accidents.

RIS could also make roads safer, by helping cars and traffic systems to "talk" to each other. For instance, RIS panels on highway signs could provide drivers with real-time updates about traffic jams or other road hazards, improving traffic flow and preventing accidents.

BIG CHALLENGES, BIGGER OPPORTUNITIES

There are a few challenges still to be solved before RIS can become a common part of our wireless networks.

One big hurdle is the cost. The special metamaterials and advanced systems needed for RIS are expensive, which makes it hard to use this technology in many places. Researchers are working on ways to lower costs so RIS can be used more widely. Another challenge is setting clear rules and standards. RIS interact with electromagnetic waves, so it is important to make sure that they work safely without interfering with other devices that rely on the same signals, like cell phones, Wi-Fi routers, or GPS systems.

Despite these challenges, the future of RIS looks bright. Big technology companies, are investing in this technology, increasing the likelihood that it will play an important role in future communication networks. By turning ordinary surfaces into intelligent tools for wireless communication, RIS could help create networks that are smarter, greener, and more reliable for everyone.

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YOUNG REVIEWERS

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I am an avid book reader, and I am fond of writing critical reviews of books that I read. English and Science are my favorite subjects. I like to play chess when I am not reading. I am also curious to know more about things around me. I am an animal lover, and I love to play with my pet birds and feed them.

AUTHORS

MOHAMED-SLIM ALOUINI

Mohamed-Slim Alouini was born in Tunis, Tunisia. He earned his Ph.D. from the California Institute of Technology (Caltech) in 1998 before serving as a faculty member at the University of Minnesota and later at Texas A&M University at Qatar. In 2009, he became a founding faculty member at King Abdullah University of Science and Technology (KAUST), where he currently is the Al-Khawarizmi Distinguished Professor of Electrical and Computer Engineering and the holder of the UNESCO Chair on Education to Connect the Unconnected. Dr. Alouini is a Fellow of the IEEE and OPTICA and his research interests encompass a wide array of research topics in wireless and satellite communications. He is currently focusing on addressing the technical challenges associated with information and communication technologies (ICT) in underserved regions and is committed to bridging the digital divide by tackling issues related to the uneven distribution, access to, and utilization of ICT in rural, low-income, disaster-prone, and hard-to-reach areas. *slim.alouini@kaust.edu.sa

MARCO DI RENZO

Marco Di Renzo is a scientist who studies how wireless communication works and how to make it faster and more efficient. He is a Research Director at the French National Center for Scientific Research (CNRS) and works at the Laboratory of Signals and Systems at Paris-Saclay University. His research focuses on developing smart

technologies, like reconfigurable intelligent surfaces, that help improve internet and phone connections. Dr. Di Renzo has received several awards for his contributions to wireless communication and helps shape the future of how people and devices stay connected.

JAVIER GARCIA MARTINEZ

Javier Garcia Martinez is a scientist and professor of chemistry at the University of Alicante in Spain, where he leads the Molecular Nanotechnology Laboratory. His research focuses on creating new materials at the tiniest scale—nanotechnology—to make energy production cleaner and more efficient. His discoveries have helped reduce pollution and improve how industries use chemical processes. Dr. Garcia Martinez has also started a company to bring his scientific ideas to the real world. He was the President of the International Union of Pure and Applied Chemistry (IUPAC), the organization that creates the rules to name new molecules and promotes chemistry worldwide.