Reconfigurable Intelligent surfaces for 5G and 6G coverage Enhancement

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Abstract:

Modern wireless communication networks continue to grow at a very rapid rate which has increased the demand for intelligent and efficient communication networks. However, all dynamic and adaptive features of wireless networks are controlled by either the Base-Station (BS) or the User Equipment (UE) while the wireless propagation environment remains unaware of various communication processes going through it. It therefore remains an open topic of research and evaluation among the industrial and academic fraternity to impart some level of intelligence to this otherwise passive radio propagation environment. Reconfigurable Intelligent Surface (RISs) are a promising technology that can address the aforementioned challenges by sensing the environment, recycling the existing radio waves and enabling non-line-of-sight (NLoS) communications. RIS can achieve this by manipulating those electromagnetic (EM) waves which are impinging on it and redirect them to the desired angle with a relatively low power consumption. At 6GIC, University of Surrey we have developed world's first reflective and transmissive metasurface for O2O, I2I, and O2I coverage enhancement. In this paper we summarise our achievements and RIS potential impact and use cases for 5G/6G netwrok.

Background

Future wireless networks are required to interconnect a huge number of online devices with ever-increasing demands for higher data rates especially in a dense urban environment where the presence of a large number of buildings and infrastructure gives rise to harsh propagation conditions for the EM waves. Moreover, existing wireless network operators face three significant challenges:

- lack of seamless connectivity leading to poor quality of service (QoS) especially in harsh propagation environments;
- supporting billions of online devices with such high data rates which ultimately results in a higher carbon footprint of the network; and
- uneven user distribution due to various practical challenges in the urban environment leading to an unequal resource utilisation at the BSs.

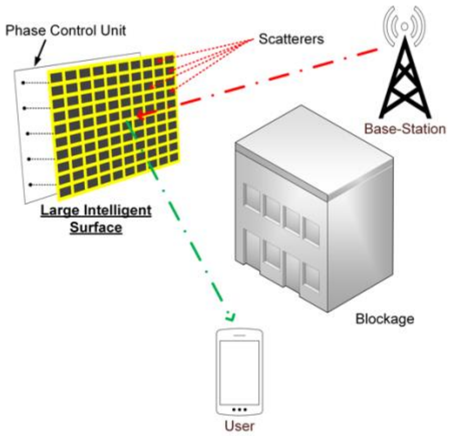

Fig.1 RIS assisted Smart Radio Network

Sensing the environment, recycling existing radio waves and enabling non-line-of-sight (NLoS) communication can play a major role in the transformation of existing wireless networks towards a highly efficient and coverage enhanced network which can deliver high QoS and seamless connectivity to a huge number of subscribers. RIS is a core component to address the aforementioned challenges as it offers the capability of manipulating the EM waves towards the direction of interest. RIS is composed of a large metasurface sheet backed by a phase control unit. The metasurface consists of a number of conductive printed patches (scatterers), where the size of each scatterer is a small proportion of the wavelength of the operating frequency [1]. The macroscopic effect of these scatterers defines a specific surface impedance and by controlling this surface impedance, the reflected wave from the metasurface sheet can be manipulated. Each individual or a cluster of scatterers can be tuned by different phase values in such a way that the whole surface can reconstruct EM waves with desired characteristics without emitting additional radio waves. Although, ultra-dense networks can be a solution for coverage enhancement, they can increase the interference level and require backhaul planning along with higher infrastructure management costs. Using co-operative BSs would also require higher density while switching to sub-6GHz during mmWave coverage outage might solve the coverage issue but would compromise the throughput and reduced QoS due to switching between radio access technologies (RATs). On the contrary, RIS does not suffer from these issues and does not require intense backhaul planning. Another disadvantage of the existing system, which relies on active elements such as relays, is the heightened power consumption and reduced network efficiency. RIS, on the other hand, can be made of smart elements that are not impaired by noise amplification. They are thus capable of controlling the state of individual elements and can sense the environment to cut down power consumption. Furthermore, RIS can improve coverage by forming strong NLoS path where the LoS path is either blocked or not sufficiently strong. Thus, RIS technology can be used as a tool to control, assess and program the channel propagation which can give rise to a more reliable and robust wireless radio environment.

Societal and Economic Impact

“The National Infrastructure Commission” in their report “Connected Future” published in 2016 proposed a concept of “Meaningful Coverage” in their report which can be defined as mobile service that is good enough both in terms of signal strength and signal quality to ensure that various Quality of Service (QoS) requirements of a specific service are met for the end-user to use it for a specific purpose. The National Infrastructure Commission presented an eye-opening fact for the industry, that UK ranks lower than expected in terms of meaningful coverage and that ≤65% of the users have access to meaningful LTE coverage. This was followed by an advisory report from Ofcom stating that ensuring mobile connectivity to UK’s society is a top priority which was followed by a briefing paper tabled in the House of Commons stating the Government’s commitment towards ensuring mobile connectivity. This gap was acknowledged by the industry and since then the wireless communication industry has been investing heavily in infrastructure to address this issue. It is our strong belief that the wireless communication industry and our digital society can benefit heavily from RIS technology as it can help immensely in improving the state of wireless communication networks, especially under harsh propagation conditions. This is possible because RIS can provide a certain level of intelligence and control over the otherwise passive and uncontrolled radio environment. RIS technology has the versatility to be adopted for any kind of environment such as buildings, sign-posts, windows etc and therefore has fewer limitations when it comes to physical deployment. Besides, as our economy soars ahead in the connected era, digital technology is expected to be the fuel that will propel it to even further heights. As we look towards the future of our economy, we can foresee a massive demand for wireless connectivity throughout the business fraternity in the UK due to the rapid adoption of technology across several business sectors. This compels us to work on techniques that can empower wireless technologies with both capacity and coverage at the same time ensuring that the technology is ready to deliver what the business sector requires from it. As RIS has the potential to deliver on both these fronts, it can be a game-changer for expansion of digital business and can put UK in the lead to become a fully digital economy. All efforts invested now towards advanced wireless technologies will pave the way for a wireless network infrastructure that is both robust and more than equipped to support successive generations of wireless technologies, 5G, 6G or Next-Gen Wi-Fi. RIS, if used in combination with state of-the-art technologies for wireless communication can improve the cost and energy efficiency of wireless networks as it works on the principles of re-using the existing electromagnetic waves efficiently rather than generating new ones.

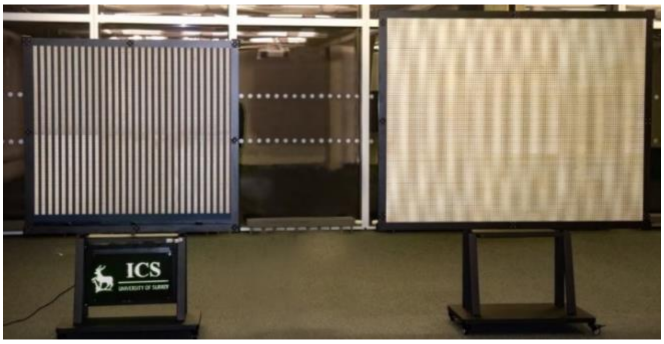

Fig.2 The world’s first RIS demo at 6GIC. The left-side one can dynamically change the beam while the one on right has fixed reflected beam with no need of electrical power.

6GIC RISs

The dynamic RIS developed at 6GIC contains 2430 unit cells [1]. The varactor diode is placed in the gap between the patches while with a relatively low reverse voltage, this diode provides a specified high capacitance ratio which makes it an appropriate candidate to regulate the phase response of the unit cell. By varying the reactance value of the varactor diode, phase of the reflected wave can be tuned in order to reconstruct the beam towards the angle of interest. Besides, two transmissive metasurfaces coated on a glassy window to enhance the 5G O2I coverage inside vehicles and buildings. Both metasurfaces are optically transparent as Indium Tin Oxide (ITO) is used as a conductive part of each unit cell. The proposed transmission surfaces empower the indoor coverage of 5G signals at 3.5 GHz band for wide range of incident angels. Both proposed transmissive surfaces offer wide angular stability up to 65 and 75 degrees for double-and single-glazed glass accordingly.

Fig.3 Transparent Transmission surfaces

References

[1] A. Araghi, Mohsen Khalily, et.al., " Reconfigurable intelligent surface (RIS) in the sub-6 GHz band: Design, implementation, and real-world demonstration. 2022.

[2] A. Bagheri, Mohsen Khalily, et al. " Enhancing 5G Propagation into Vehicles and Buildings using transparent Metasurfaces, 2022.