Beyond 5G: How Cognitive RAN Can Revolutionize Cellular Networks

Parag Naik - Managing Director and CEO, Saankhya Labs

The shift to 5G networks has prompted a broader perspective on the technology's advantages and potential shortcomings, moving beyond the notion of "Just a faster 4G". This viewpoint, dubbed as the "inside out" approach, delves into the intricate details of the telecom infrastructure rather than focusing solely on surface-level benefits.

The architectural landscape of 5G networks, especially green-field ones, resembles the structure of an "IT Cloud" deployment. Just as the foundation of IT cloud setups is built upon open-source components, 5G networks adopt an open architectural framework called O-RAN. The primary principles underlying these networks encompass virtualization, disaggregation, and densification.

Virtualization involves implementing network components not just as software, but as a specific architectural configuration that renders software components "cloud-native." Even the traditionally hardware-dependent Layer 1 of the RAN (Radio Access Network) has shifted toward virtualization in most 5G implementations.

Disaggregation is characterized by the breaking down of the complex RAN into distinct segments and connecting them via backplanes or fibre-optic links. This approach enables the construction of networks like assembling Lego blocks, allowing diverse components to be sourced from different vendors.

Densification refers to maximizing spectrum reuse, a crucial aspect of 5G networks with their varied topologies, including macro, small, femto, and private cells. The high-frequency millimetre wave (FR2) necessitates an exceptionally dense network structure.

These principles collectively form the basis of the "Virtualized RAN." However, despite the robust infrastructure of 5G, there are several fundamental flaws in cellular network design that need attention.

Historically, network design prioritized spectral efficiency enhancements such as better coding techniques and massive multiple-input multiple-output (mMIMO) systems. But as 5G approaches the theoretical limit of communication capacity set by Claude Shannon, improvements in speed predominantly rely on increased bandwidth, which is primarily available in high-frequency spectrums.

1. Static and Worst-Case Provisioning: Existing network deployment assumes worst-case scenarios, neglecting the dynamic nature of the RF environment. Networks designed primarily for cell-edge performance result in pessimistic designs that penalize the average user. This flawed approach leads to spectrum wastage of around 25%.

2. Limited Spectrum Sharing: While some spectrum-sharing mechanisms like Wi-Fi and CBRS have emerged, they are still at a basic level. A more advanced form of spectrum sharing is required to unlock statically allocated yet unused spectrum, enhancing spectral efficiency.

3. Limited Network Observability: Current observable physical layer metrics like RSRP, RSRQ, CQI, and RSSNR are insufficient for comprehensive network optimization. Expanding observability to include metrics like Channel Impulse Response can facilitate untapped opportunities for optimization through Machine Learning.

Cognitive RAN scheme for optimal radio performance

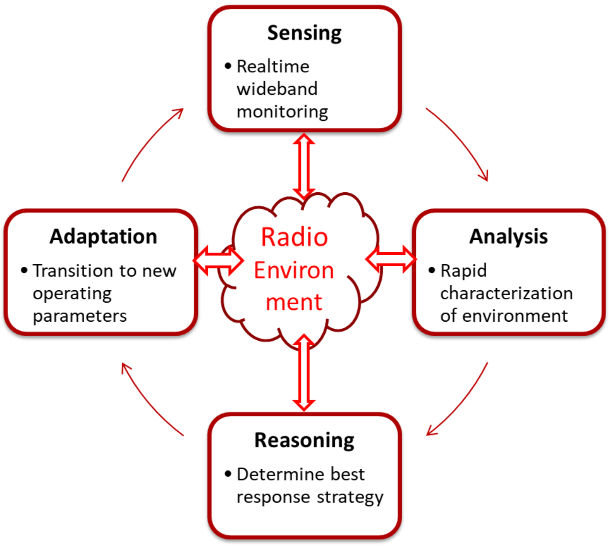
To address the above issues, the evolution towards 6G should adopt a cognitive approach, enabling auto-tuning and adaptability. The future 6G Radio Access Network (RAN) should possess inherent sensing capabilities, allowing it to dynamically adjust to changing radio environments. This cognitive RAN concept involves the following four phases:

1. Sensing Phase: The radio environment is monitored through wideband sensing and scanning, as well as by utilizing previously captured data.

2. Analysis Phase: Data from the sensing phase is processed to characterize the radio environment, including available frequency bands, interference levels, and various other parameters.

3. Reasoning Phase: Inputs from the analysis phase are used to determine optimal communication schemes and associated parameters for establishing successful radio links, based on chosen cost functions.

4. Adaptation Phase: The RAN transitions to the newly designed radio links and modulation schemes identified in the reasoning phase.



The cognitive RAN seeks to optimize radio performance continually by adapting modulation and demodulation schemes based on specified cost functions. This approach utilizes deep learning methods to allocate resources optimally, resulting in personalized waveforms for each device entering the network.

In a nutshell, the "inside out" view of 5G and its flaws underscores the need for a more innovative and dynamic architecture for future networks like 6G. A cognitive RAN that can adapt to changing conditions and optimize resources holds the promise of revolutionizing wireless communication, moving beyond the simplistic view of mere speed improvements.