Chapter 7
Cloud Radio Access Networks

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ABSTRACT

Radio virtualization and cloud signal processing are new approaches to building cellular Radio Access Networks (RAN) that are starting to be deployed within the cellular industry. For cellular operators, Cloud RAN architectures that centrally define or decode transmissions, placing most of the base-station software stack within a data-centre, promise improvements in flexibility and performance. The expected benefits range from standard cloud economies—statistical reductions in total processing, energy efficiency, cost reductions, simplified maintenance—to dramatic changes in the functionality of the radio network, such as simplified network sharing, capacity increases towards theoretical limits, and software defined radio inspired air interface flexibility. Because cellular networks have, in addition to complex protocols, extremely sensitive timing constraints and often high data-rates, the design challenges are formidable. This chapter presents the state of the art, hybrid alternatives, and directions for making Cloud Radio Access Networks more widely deployable.

INTRODUCTION

For the sake of simplicity, radio systems are often studied and designed around a model of a single transmitter and a single receiver. Real networks are rarely so simple. Commercial cellular networks typically contain thousands of base stations and millions of handsets. The large scale of these networks makes most of their challenges internal: data rates are limited by in-system interference and much of the cost of these systems stems from the complexity of the protocols for coordination between the elements. In the design of each generation of these networks, choices are made about how communications functions are split between different elements of the radio network. These choices balance performance, feature support, implementation and operational complexity and cost, but they also reflect the outlook of the people and organizations that develop them.

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The design of fourth generation cellular networks began in the late 1990s as IP technologies eclipsed ATM. In addition to having IP interfaces, they embody IP design principles: they are data-centric, decentralized, and flat, with greater independence of base-stations from the core network than in previous generations. In current LTE radio standards (3rd Generation Partnership Project, 2012), radio resource management and user-plane encryption have been migrated from a network element serving many base-stations – the UMTS Radio Network Controller – to be intrinsic to each base-station. Though much of the frontier of the Internet is now in the data-centre, the wireless industry's long technology cycle sees it pushing more of its processing to the edge.

No architecture is permanent. Capable cloud-computing technology and the structural benefits it offers are encouraging operators to look at centralizing and virtualizing more of their radio networks' functions. Cellular data demand forecasts that far outstrip spectrum supply are pushing operators to pursue higher spectral efficiency in addition to increased cell deployment. Cooperative techniques that lead to higher spectral efficiency benefit greatly from centralized processing – cooperation is much easier to achieve across a backplane than a backhaul. Software centralization, similarly, can simplify the self-organization functions intended to allow for a large increase in deployed cells without a similarly large increase in network operations, and it can help to secure smaller cells deployed with reduced physical security and monitoring. Full centralization of the base-station's modem functions facilitates virtualization of the radio access, and can allow operators to cleanly share their access radios, trial and upgrade to newer cellular protocols, or reallocate air resources between protocols.

Cloud infrastructure is coming of age. The proliferation of large data-centres and rapid advances in data-centre economics, networking, virtualization, and management make centralized infrastructure increasingly attractive. For many operators, fibre-connected base-station sites offer the data-rates to transfer cellular waveforms back to the data-centre. Packet networks have advanced to support precise time and frequency synchronization and ultra-low latency switching; these features can allow a single packet network to carry radio plane data in addition to control and user plane data. The Cloud revolution has created the ingredients for carriers to deploy cooperative radios over commercial IP / Ethernet networks.

The purpose of this chapter is to explain what Cloud radio access networks are, why operators are becoming interested in them, how they may affect cellular system evolution, and what some of their long term challenges and frontiers are.

RADIO NETWORK VIRTUALIZATION

Cloud Radio Access Networks rely on two components: a method of separating the antenna or radio from the signal processor—wireless virtualization—and a high volume "Cloud" signal processor network to host and execute the radio baseband and MAC—a Cloud modem.

Just as there is a long history of virtualization in computing and a large body of knowledge on virtualization in networking, there have been many approaches to abstracting, sharing, remoting, or virtualizing radio. There are many successful implementations of antenna remoting – today's cable networks started as CATV networks where a single receive antenna was shared throughout a town via coaxial cable and a chain of amplifiers, and modern Hybrid Fibre-Coax cable networks still do large scale analog distribution of RF signals. Many of the cellular Distributed Antenna Systems designed to provide in-building cellular coverage use very similar components to split a transmission to and combine receptions from a