OpenRAN: A Software-defined RAN Architecture Via Virtualization

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ABSTRACT

With the rapid growth of the demands for mobile data, wireless network faces several challenges, such as lack of efficient interconnection among heterogeneous wireless networks, and shortage of customized QoS guarantees between services. The fundamental reason for these challenges is that the radio access network (RAN) is closed and ossified. We propose OpenRAN, an architecture for software-defined RAN via virtualization. It achieves complete virtualization and programmability vertically, and benefits the convergence of heterogeneous network horizontally. It provides open, controllable, flexible and evolvable wireless networks.

Categories and Subject Descriptors

C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design, Wireless communication

General Terms

Design

Keywords

Software-defined network; wireless virtualization; radio access network

1. INTRODUCTION

With the rapid growth of mobile data demands [5] and the increasing prosperity of mobile Internet, mobile wireless networks will keep growing at high speed. However, wireless network has to face several intractable challenges. First, while there exist various heterogeneous wireless networks, i.e., pluralistic standards, they can hardly interconnect. It wastes plenty of wireless infrastructures and spectrum resources [4]. Second, wireless services proliferate significantly, and different services require different network characteristics. Unfortunately, ignoring these differences and just supporting them with the same network characteristics, current wireless network leads to low QoS and QoE. The main reason is that the radio access network (RAN) is closed and ossified. This is due to the neglect of network state and flexible control. Although there may be considerable wireless networks around us, we cannot access the most appropriate one or select multiple networks to support us simultaneously. The only thing we can do is to access the specific network all the time, even if this network performs quite poorly.

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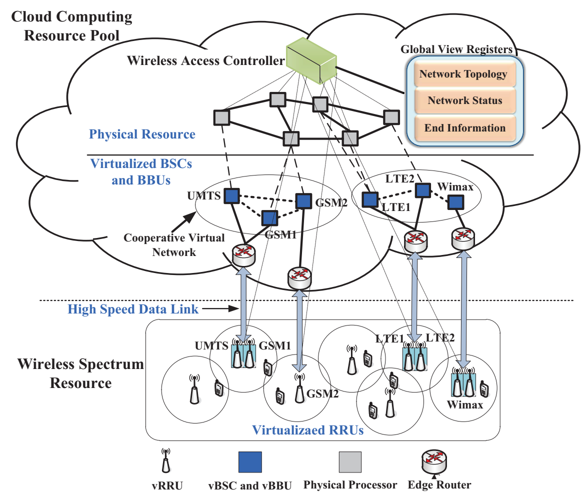

Figure 1: Architecture Overview of OpenRAN.

To deal with the issue raised above, it calls for a more open and efficient architecture for radio access network. Software-defined network (SDN) proposed for wired networks makes them much more controllable, programmable and flexible [6]. Bansal *et al.* [1] extend SDN into wireless network. China Mobile Ltd. (CMCC) proposes a C-RAN architecture that introduces a cloud pool to process wireless baseband data [2]. Moreover, wired network virtualization, e.g. cloud computing, and wireless virtualization technologies also provide us promising ways for the future network. However, most related work focuses on part of the problem and hardly possesses the generality.

Addressing the closure and ossification of RAN, we propose OpenRAN, a software defined RAN architecture via virtualization. Our proposed architecture achieves complete virtualization and programmability, which makes RAN more open, controllable, flexible and evolvable.

2. ARCHITECTURE DESCRIPTION

2.1 OpenRAN Overview

The overview of our software-defined RAN architecture is shown in Fig. 1. It contains three main parts: wireless spectrum resource pool (WSRP), cloud computing resource pool (CCRP) and SDN controller.

WSRP consists of multiple physical remote radio units (pRRUs) distributed at various locations. To efficiently support heterogeneous networks convergence, WSRP virtualizes spectrum by RF virtualization technology, which enables several virtual RRUs (vRRUs) with different wireless protocols coexisting in one shared pRRU. For example, as shown in Fig. 1, one pRRU can simultaneously support two vRRUs running UMTS and GSM respectively.

CCRP is comprised of a large amount of physical proces-

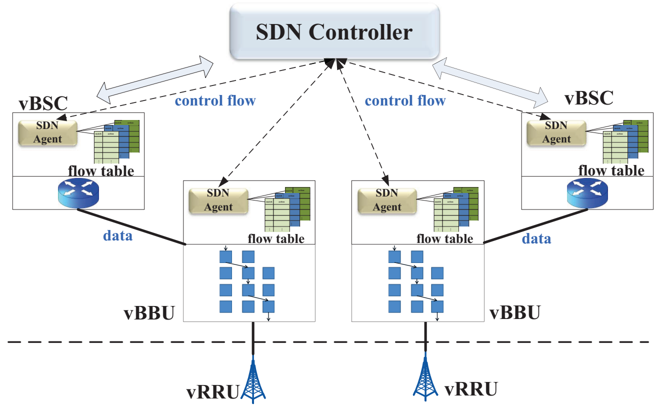

Figure 2: SDN control strategy and programmable scheme.

sors which construct a high speed cloud computing network. Different from the vertical networking method adopted by current wireless access network, in this system traditional base band units (BBUs) and base station controllers (BSCs) do not exist any more. They are replaced by virtual ones (vBBUs and vBSCs) deployed in shared physical processors by virtualization technologies. After that, these virtual access elements, including vBSCs, vBBUs and vRRUs, constitute a complete RAN. Without loss of generality, we also use BSCs to represent the RNCs in 3G, and *etc*.

SDN controller is the control plane of heterogeneous RANs by abstracting and combining control functions of the access elements. It determines the strategies of each vBBU and vBSC, and each virtual access element contains a SDN agent to communicate with controller through SDN protocol.

2.2 Virtualization

Our architecture contains four levels of virtualization: application level, cloud level, spectrum level, and cooperation level. 1) In application level virtualization, flow space is divided and each virtual space operates and manages its own control strategies. In this case, virtual spaces correspond to several network operators or services. 2) In cloud level virtualization, SDN controller creates vBBUs and vBSCs by virtualizing physical processors and allocating appropriate computing and storage resources. 3) Spectrum level virtualization refers to the virtualization of spectrum by RF virtualization technology, which enables several vRRUs with different wireless protocols to coexist in one shared pRRU. 4) Cooperation level virtualization constructs several virtual networks, including virtual nodes and virtual links. This is because cooperative communication among multiple vRRUs benefits the inter-cell interference elimination, and it calls for communications between different vBBUs and vBSCs.

2.3 SDN Control Strategy

We adopt flow based centralized control method in our architecture. The controller creates and dynamically optimizes the virtual access elements according to the requirements by efficiently and fairly virtualizing and allocating spectrum, computing and storage resources to virtual access elements. We adopt flow based "match-action" control strategy. Packet header in each flow has several match fields such as IP address, mac address and port. Each virtual access element has a unified SDN agent to resolve the control flow. The controller sets the rules in each virtual access element. When one element receives a packet, it first checks whether this flow can match its control rules. If so, it executes the corresponding action. Actions in different virtual access elements may be different, e.g. vBSC may route the data but vBBU possibly executes power control. SDN control strategy makes RAN more **open** and **flexible**.

2.4 Programmable Scheme

Current wireless networks and corresponding instruments are complicated and difficult to control and customized [3]. Our architecture is deeply programmable in both control plane and data plane, which makes RAN more **controllable** and **evolvable**. In the control plane, the SDN controller has the capability of establishing or modifying the rules in each virtual access element, such as routing, bandwidth allocation and setting flow priorities. In the data plane, although different wireless protocols operate quite different from each other, they always share some modules, such as modulation, coding and interleaving. Inspired from software defined radio, we modularize wireless protocols in vBBUs. After that, each vBBU chooses and combines the appropriate modules to implement the wireless protocol, as shown in Fig. 2.

3. AN EXAMPLE

As Fig. 1 shows, one carrier wants to establish a UMTS network and two GSM networks in two adjacent areas. First, the controller estimates the resources that each network needed in view of the requirements and actual network characteristics. Second, the controller creates vRRUs, vBBUs and vBSCs by allocating appropriate spectrum, computing and storage resources to them via spectrum level and cloud level virtualizaiton. Third, the controller sends flows to configure the data processing rules in vBSCs and deploy corresponding wireless protocols in vBBUs by programmable scheme. Forth, since three vRRUs are distributed in neighboring cells, in order to eliminate the interferences among them, the controller deploys one cooperation virtual network. Fifth, by application level virtualization, controller provides an operating virtual network that satisfies the requirements of the carrier.

4. ACKNOWLEDGMENTS

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