CCAMP Working Group J. Zhang, Ed.
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An Unified Control Plane Architecture for the convergency of radio and optical networks
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Abstract

This memo specifies an unified radio and optical control architecture based on Software Defined Networking (SDN). The architecture is designed for the purposes of end-to-end 5G Radio Access Networks (RAN) service, which enables joint radio and optical network resoures orchestration. Based on this architecture, some new applications could be achieved, such as enhanced Coordinated MultiPoint (eCoMP) service, Baseband Unit (BBU) aggregation, fronthaul traffic prediction and so on.

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1. Introduction

This memo introduces an unified radio and optical network control architecture based on the Software-Defined Networking (SDN). The architecture consists of three planes: application plane, control plane, and data plane. For data plane, each physical node of radio and optical networks (i.e., BBU, RRU, and optical transport node) is attached with an OpenFlow agent (OF-Agent) that communicates with the OpenFlow controller through the extended OpenFlow protocols (OFP). For the control plane, it realizes the control of the physical devises,such as configuration of optical/radio network nodes and the information collection of network statuses. In addition, the control plane realizes radio and optical resources virtualization, and performs joint resourses allocation (orchestration).The application plane consists of various services, and each service injects a policy rule to the control plane for orchestrating radio and optical resources.

2. Requirements Language

The key words are "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL".

3. Terminology

This memo uses the following terms: SDN, BBU, RRU, Service, Interface, Control.

This document uses the following terms:

OpenFlow Agent (OF-A): is associated with a physical node to communicates with the controller through extended OpenFlow protocol (OFP).

Radio-Controller (Radio-C): is used to control wireless network devices.

Transport-Controller (Transport-C): is used to control optical network devices.

Resource Maintenance (RM): is to collect and maintain physical resource information.

Protocol Control (PC): is to code/decode extended OF messages.

Integrated Traffic Engineering Database (Integrated-TED): is a database to store virtualized radio and optical resources which are abstracted from raw physical resources.

Virtual Optical Resource (VOR): abstracts the raw data of optical physical network which are reported from the RM module.

Virtual Radio Resource (VRR): abstracts the raw data of radio physical network which are reported from the RM module.

Orchestrator Engine: is an execution module which has two functions,lightpath management and radio resource mapping.

Lightpath Calculation(LPC): is used to establish lightpaths for the connections .

Radio Resource Mapping(RRM): is responsible for mapping RRU-BBU pairs .

Policy Injection: the scheduling scheme for eCoMP , BBU aggregation scheme and fronthaul traffic prediction could be running in it.

South Bound Interface (SBI): the interface between control plane and data plane.

Noth Bound Interface (NBI): the interface between application plane and control plane.

4. Motivation and Goals

The radio access network (RAN) architecture towards mobile 5G and beyond is undergoing a fundamental evolution, which brings optics into the radio world. Fronthaul is a new segment that leverages on the advantages of optical communication for RAN. However, the current fronthaul architecture shows a fixed connection between an RRU and a BBU, which leads to inefficient resource utilization.In addition, the existing network control architectures of radio and optical networks are built independently, where the convergence of radio and optical networks is inefficient in terms of end-to-end delay and joint resources allocation. Therefore,to provide a good RAN performance, an unified control plane architecture for radio and optical networks SHOULD be proposed.

SDN is an emerging paradigm that promises to change this state of affairs, by breaking vertical integration, separating the network’s control logic from the underlying devices, promoting (logical) centralization of network control, and introducing the ability to program the network. SDN makes it easier to create and introduce new abstractions in networking, simplifying network management, especially for the convergence of different network pardigms.

Based on the advantages of SDN, we have established an radio and optical control architecture to achieve new applications, such as eCoMP service, BBU aggregation, and fronthaul traffic prediction, which are shown as follows.

4.1. BBU aggregation

BBU aggregation is to turn off the low-utilized BBUs and migrate their RRUs to other active BBUs through lightpath reconfiguration. With the help of BBU aggregation, BBU resource utilization can be significantly improved, and this is enabled through the unified radio and optical networks control architecture.

4.2. eCoMP

The eCoMP exploits the fronthaul flexibility by dynamically reconfiguring the lightpath between RRUs and BBUs, which is to reassociate coordinated RRUs (connected to different BBUs) within a single BBU. With the help of eCoMP, several geographically-adjacent RRUs jointly process/transmit as a single antenna system that serves for the cell-edge users.It realizes the backhaul bandwidth saving between the coordinated BBUs.

4.3. fronthaul traffic prediction

The date rate of new fronthaul interfaces, such as eCPRI and NGFI CPRI, are depending on the wireless traffic load. Therefore, the wireless traffic prediction is an important thing to improve the fronthaul bandwidth utilization. It could be predicted by using machine learning approach to perceive user’s behavior (e.g.,traffic load, mobility), which can be enabled by this unified control architecture.

5. Overview of Radio and Optical Network Control Architecture

```
     o-----------------------------------------------------------------o
     | +------+      +-----------------+       +-------------------+   |
     | |eCoMP |      | BBU Aggregation | ...   |Traffic Prediction |   |
     | +------+      +-----------------+       +-------------------+   |
     |                 Application    Plane                            |
     o----------------------------|------------------------------------o
                                  |North Bound Interface (NBI)
                                  |
     o----------------------------Y------------------------------------o
     |                    +----------------------+                     |
     |                    |   Policy Injection   |                     |
     |                    +------Y-----------Y---+                     |
     |              -------------|           |------------             |
     |              |                                    |             |
     |   +----------Y----------+             +-----------Y----------+  |
     |   |    Inergrated TED   |             | Orchestrator Engine  |  |
     |   |    ----     ----    |             |   ----      ----     |  |
     |   |   |VOR |   |VRR |   Y-------------Y  | LPC|    | RRM|    |  |
     |   |    ----     ----    |             |   ----      ----     |  |
     |   +----------Y----------+             +----------Y-----------+  |
     |              |                                   |              |
     |   +----------Y----------+             +----------Y-----------+  |
     |   | Transport Controller|             |   Radio  Controller  |  |
     |   |    ----     ----    |             |    ----     ----     |  |
     |   |   |VOR |   |VRR |   |             |   |VOR |   |VRR |    |  |
     |   |    ----      ----   |             |    ----     ----     |  |
     |   +---------------------+             +----------------------+  |
     |                                                                 |
     |                    Control     Plane                            |
     o----------------------------|------------------------------------o
                                  | South Bound Interface (SBI)
                                  |
     o----------------------------Y------------------------------------o
     |                                                                 |
     |   +-------Y------+     +-------Y------+    +--------Y-------+   |
     |   |  RRU_Agent   |     |   BBU_Agent  |    |    TN_Agent    |   |
     |   +--------------+     +--------------+    +----------------+   |
     |                         Data    Plane                           |
     o-----------------------------------------------------------------o
```

Figure 1: Unified Radio and Optical Control Architecture based on SDN

The framework of SDN-enabled control architecture is consisting of three planess: application plane, control plane, and data plane, are interconnected via a northbound interface (NBI) and a southbound interface (SBI). For data plane, each physical node (i.e., BBU, RRU, and TN) is attached with an OpenFlow agent that communicates with the controller through extended OpenFlow protocols (OFP).

The control plane is consisting of five modules: Policy Injection module, Optical-Controller (Optical-C) module, Radio-Controller (Radio-C) module, and Integrated Traffic Engineering Database (Integrated-TED) module. Policy Injection (eCoMP) runs application policies, such as the eCoMP algorithm, BBU aggregration. Radio-Controller (Radio-C) is used to control radio devices. Optical-Controller (Optical-C) is used to control optical devices. Integrated Traffic Engineering Database (Integrated-TED) is a database to store virtualized radio and optical resources which are abstracted from raw physical resources.

The application layer includes some applications implemented in the framework of SDN-enabled control architecture, such as eCoMP, BBU aggregation, traffic prediction and so on.

6. Architectural Considerations of Radio and Optical Control

6.1. Interface of Control Architecture

SBI:In radio and optical control architecture, control plane and data plane are interconnected via SBI. Existing SBI includes: NETCONF, OpenFlow, SNMP, OpenCONFIG, PCEP, et al.

NBI:In radio and optical control architecture, application plane and control plane are interconnected via NBI. The NBI is mainly REST API.

7. Security Considerations

8. Acknowledgments

9. Contributors

Authors' Addresses

Jiawei Zhang (editor)
Beijing University of Posts and Telecommunications
Xitucheng Road
Beijing, Haidian District 100876
China

Phone: +86-010-61198422
Email: zjw@bupt.edu.cn

Zhen Liu (editor)
Beijing University of Posts and Telecommunications
Xitucheng Road
Beijing, Haidian District 100876
China

Phone: +86-010-61198422
Email: liuzhen207@bupt.edu.cn

Yuefeng Ji (editor)
Beijing University of Posts and Telecommunications
Xitucheng Road
Beijing, Haidian District 100876
China

Phone: +86-010-61198422
Email: jyf@bupt.edu.cn