Design and Implementation of O-RAN M-Plane System

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Abstract - This paper deals with the design and implementation of M-Plane, a standard interface for management functions between O-DU and O-RU in O-RAN based mobile communication base stations. It includes the basic structure, topology, and modeling structure for design, and the execution procedure is introduced in the form of information flow. In addition, SW structure for implementation, HW specifications, verification environment are presented.

Keywords - O-RAN, M-Plane, NETCONF, YANG, O-RU, O-DU, NMS

I. Introduction

The O-RAN (Open RAN) Alliance is a global cooperative organization in the field of mobile communication base stations, which solves high-cost/vendor-specific fronthaul problems through base station functional split and open fronthaul interfaces to reduce infrastructure construction costs and create an open mobile communication ecosystem. has a major purpose. [1]

The O-RAN system, characterized by a base station with divided functions, has four planes such as C (Control), U (User), S (Synchronization), and M (Management) for interaction between the divided elements. CUS-Plane is a communication domain for physical channel data and synchronization, which are the main operations of the base station. On the other hand, M-Plane is a communication domain required for deployment, maintenance, and operation of base stations. The interfaces of all planes are open, and standardization is in progress through the cooperation of alliance member companies. [2]

In this paper, we present the design and implementation of the management plane(M-plane) between O-DU (Distributed Unit) and O-RU (Radio Unit) in O-RAN based base station. We introduce the standardization status of O-RAN M-Plane and propose a design structure to realize it. And it also includes the verification environment for implementation, HW environment, considerations, etc.

II. O-RAN M-Plane

A. M-Plane Architecture

O-RAN M-Plane has a client-server model connected through a secure communication channel as a basic structure. M-Plane Client is the part that interacts with the system manager and is responsible for delivering user requests to the server or notifying the user of notification information from the server. M-Plane Server is responsible for performing M-Plane functions in conjunction with O-RAN RU. Communication standards between Client and Server use NETCONF & YANG, which are widely used in the open world. Fig. 1 shows the structure of O-RAN M-Plane.

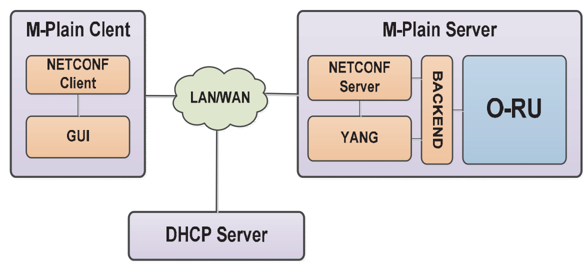

Fig. 1 O-RAN M-Plane Architecture

Fig. 2 shows the connection topology between M-Plane elements. O-RUs have Hierarchical Mode, which is a method that O-RU must be connected through only O-DU, and Hybrid Mode, which is a method that can be directly connected to a standalone O-RU NMS. Both modes can be supported simultaneously. [3]

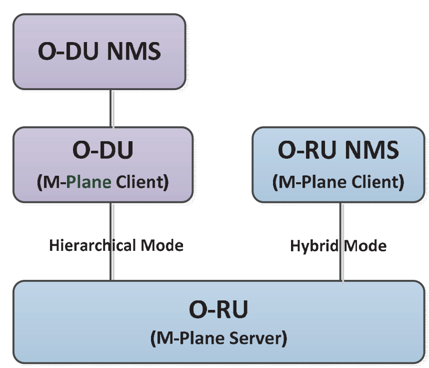

Fig. 2 O-RAN M-Plane Topology

B. NETCONF and YANG Model

NETCONF/YANG is a standardized network specification and modeling language between client and server, and is an open management method for efficient integration and management between multi-vendor O-RU and O-DU. Fig. 3 shows a conceptual diagram of such a model. Through the NETCONF/YANG concept, efficient integrated operation between different operators becomes possible.

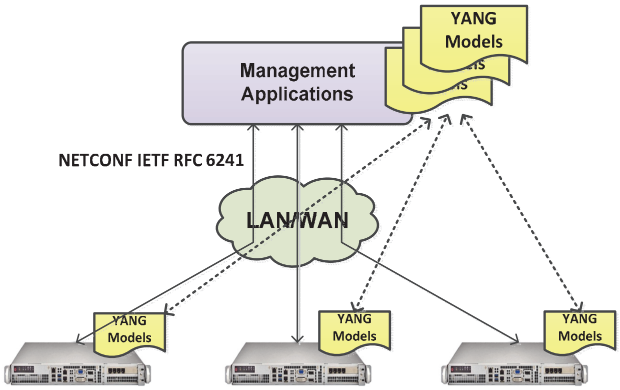

Fig. 3 NETCONF & YANG

C. M-Plane Function

O-RAN Management Plane provides the following functions to O-RU. The following functions are continuously being added through the standardization activities of the O-RAN alliance. [3][4][5]

- **"Startup" Installation:** Operations from power on to start of this service, such as IP address acquisition, NETCONF connection acquisition, capability exchange, etc.
- **U-Plane Configuration:** User data endpoint relationship setup, IQ Data Transmission settings
- **SW Management:** Download, Install, and Execute SW that requires O-RU
- **Configuration Management:** Retrieve or Modify each parameter in O-RU
- **Performance Management:** Performance related Measurement and Reporting
- **Fault Management:** Inspection and reporting of failure conditions
- **File Management:** Download and Upload various files
- **Synchronization:** Select a synchronization input source and Verify that the implemented RAT satisfies the required accuracy

III. DESINGN

A. Architecture

Fig.4 below shows the design structure of O-RAN M-Plane System. In order to support Hybrid Mode, two entities, O-RU NMS and O-DU NMS, are designed to perform M-Plane operation for O-RU. In O-RU, Netopeer2-Server for Netconf connection, SYSREPO for Yang Model processing, and Confd for O-RU PHY/RF/ANT control are used. At this time, O-RAN YANG Models are used in Netopeer-GUI, CISCO Yang Suit, and O-RAN Emulator.

On the other hand, Netopeer2-GUI for Netconf connection is used in NMS, which is a modified version of the command mode-based Netopeer2-CLI so that it can be used as GUI-based input structure. CISCO Yang Suit was deployed for mutual verification. This is to verify whether the developed O-RAN M-Plane operates in accordance with the standard. The GUI connected to Netopeer2-GUI is also connected to O-DU and designed to play the role of GUI of O-DU NMS. At this time, O-RAN YANG Models are used in Netopeer-GUI, CISCO Yang Suit, and O-RAN Emulator.

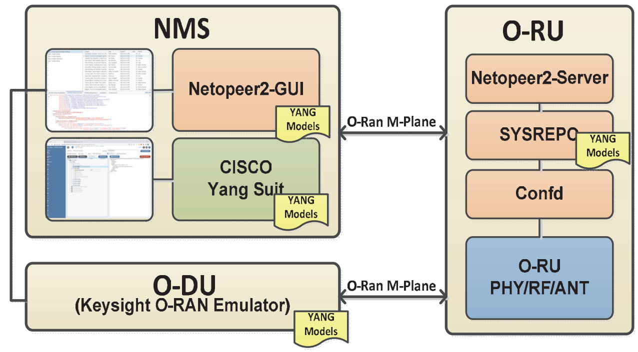

Fig. 4 Design Architecture

B. Procedure

Fig. 5 shows the operation procedure of O-RAN M-Plane based on information flow between NMS, DHCP Server and O-RU When power is applied to the O-RU, the VLAN discovery procedure is performed first, which uses the **vlan-range** field information defined in the **o-ran-implant-int.yang** module. It repeats the process of finding NMS by sequentially transmitting DHCP DISCOVER including Option 60 through each VLAN interface. In response, the DHCP Server responds with a DHCP OFFER and allocates an IP address for O-RU. At this time, it also responds with the NMS address using Option 43. Then, a TCP connection using SSH security is made between the O-RU and the NMS, and based on this connection, a NETCONF connection between the NMS and the O-RU is formed.

When a NETCONF connection is established, an operation such as RPC (Remote Procedure Call) is possible between NMS and O-RU. Representative standard RPC operations of NETCONF include "**get**", "**edit-config**", and "**get-config**", which are responsible for checking device status information, modifying device configuration information, and checking device configuration information, respectively. Each function of O-RAN M-Plane described previously is based on NETCONF RPC and O-RAN standard YANG Model.

For example, in the case of the configuration management function, in order to change the resource state of O-RU, the NMS can first find out the state of the resource through **get-config** RPC and then instruct the O-RU to change the state through **edit-config** RPC. In case of Fault Management function, we can get the alarm list operated by O-RU through active-alarm-list through **get** RPC.

IV. IMPLEMENTATION

Fig. 6 shows the implementation structure and shape of the O-RAN M-Plane System. The O-RU side is divided into an FPGA/HW part where PHY/RF is executed and a Xilinx Zynq ZCU102 based APU part where M-Plane SW operates. APU uses PetaLinux as operating system, and BSP (Board Support Package) includes libraries such as **libnetconf2**, **libssh**, **libsysrepo**, **libyang** to support secured NETCONF/YANG and **libmmap** for communication with FPGA. Confd performs the O-RAN M-Plane Server function with the support of libraries composed with PetaLinux.

There are two types of NMS, O-DU NMS and Standalone O-RU NMS. O-DU NMS used Keysight's O-RAN Emulator, which consists of Signal Studio (N7631ORNC), O-RAN Studio Explorer/Capture (U5040IQEA), and O-RAN Studio Builder/Player (U5040BSCA). In this implementation, this emulator is composed of O-DU and used as an M-plain client dealing with O-RU. Standalone NMS uses a virtualization-based server, with VMware vSphere ESXi as a hypervisor on an Intel CPU and two VMs (Virtual Machine) with Ubuntu as a guest OS on top of it. One is NMS acting as M-Plane Client and the other acts as DHCP Server.

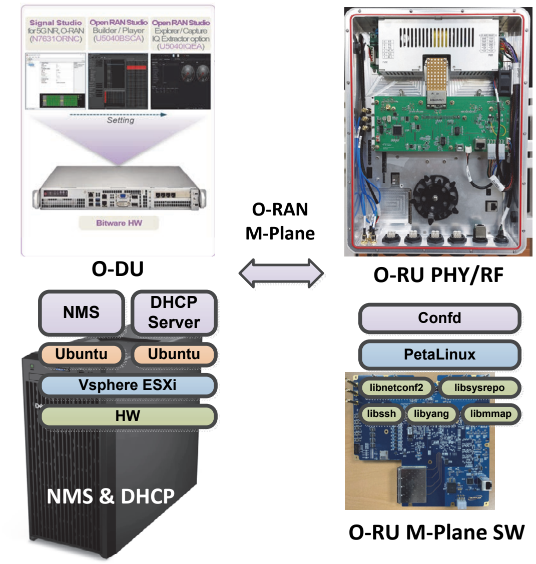

Fig. 6 Implementation

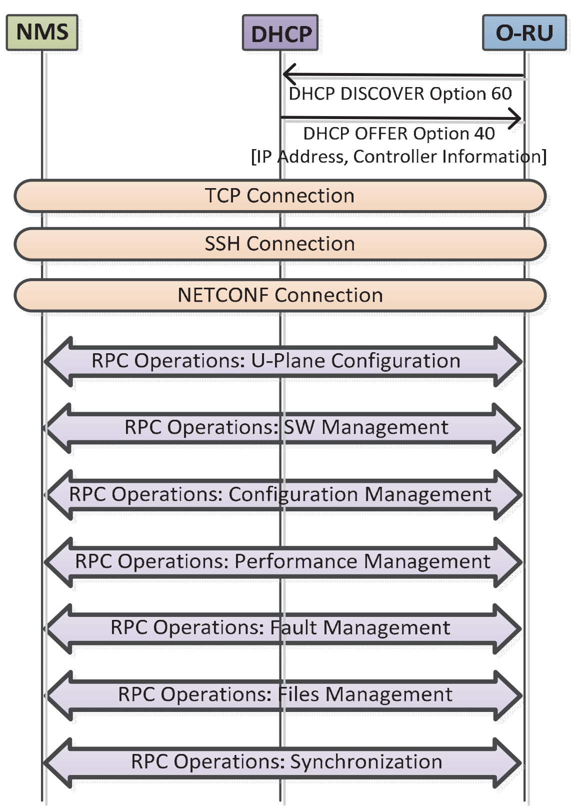

Fig. 5 Procedure

V. CONCLUSIONS

This paper deals with the design and implementation of the O-RAN M-Plane System. O-RAN M-Plane System can have consistency and scalability in managing O-RU by using standardized connection method and modeling language such as NETCONF/YANG. Therefore, it can be of great help in system integration between heterogeneous operators. On the other hand, loading heavy programs such as NETCONF, SSH, YANG, SYSREPO, and CONFD on the O-RU system can be burdensome for a small-scale O-RU, so it needs to be considered.

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[4] O-RAN.WG4.IOT.0, “O-RAN Fronthaul Working Group Fronthaul Interoperability Test Specification (IOT)”

[5] O-RAN.WG4.CONF.0, “O-RAN Fronthaul Working Group Conformance Test Specification”