Field Trial of End-to-end Management and Control of Semi-active WDM System for 5G Centralized Front-haul Network

Yang Zhao[1], Jiang Sun[1], Haomian Zheng[2], Chaode Yu[2], Dong Wang[1], Qian Cai[1], Yunbo Li[1], Liuyan Han[1], Dechao Zhang[1] and Han Li[1, *]

[1]Department of Network and IT Technology, China Mobile Research Institute, Beijing 100053, China
[2] Optical System & Algorithm Development Department, Huawei Technologies Co., Ltd., Wuhan 430223, China
**lihan@chinamobile.com*

Abstract: A novel management and control architecture and abstract model of semi-active WDM system for 5G front-haul network are proposed. The functions of device information acquisition, alarm monitoring and fault location is demonstrated in field trial.

1. Introduction

In the 5th Generation Mobile Communication Technology (5G for short) era, the centralized radio access network (C-RAN) is favored by many operators, which is beneficial to saving equipment room resources, reducing power consumption, and facilitating DU pooling and collaboration [1-3]. The 5G C-RAN front-haul network is more complex than 4G (D-RAN) front-haul network, more and more attention is also paid to the operation, maintenance and management of the Front-haul system [4, 5].

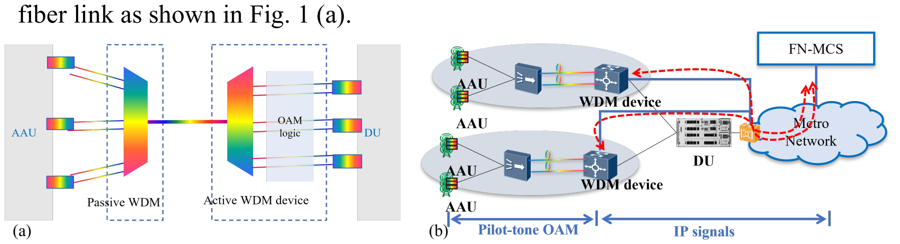
In the 4G era, due to lack of dedicated front-haul management and control capabilities, for front-haul network managed by the wireless management and control system, there were problems with hard fault demarcation and low maintenance efficiency. It was also unable to satisfy high reliability, energy saving, easy deployment and low cost requirements required by 5G C-RAN. Therefore, a semi-active Front-haul architecture was proposed[6, 7].

In the semi-active Front-haul architecture, the WDM device on DU side is active while the WDM device on the AAU side is passive. This semi-active architecture supports unified management and control, improve the reliability and maintainability of the Front-haul network, and is easy to deploy. It has attracted wide attention from operators and experts once it was proposed. However, the remote passive optical modules don't meet the condition of supporting traditional management and control signaling. Therefore, a new Front-haul management and control solution is required to implement end-to-end management and control of the Front-haul systems.

Here we propose a front-haul management and control system (FH-MCS) solution. FH-MCS deployed in the core equipment room, can establish management and control information communication with active WDM devices at DU side by IP signals. Pilot-tone OAM channels are used to establish connections between active WDM device and remote optical modules. At the same time, we propose a novel abstract model to achieve end-to-end centralized management and control of front-haul systems of different vendors.

2. Overview of Semi-active System and Management Architecture

The Open WDM system mainly includes color optical modules, passive de/multiplexer at the AAU side and WDM device at the DU side [5, 6]. The de/multiplexers between AAU side and DU side are connected through optical fiber link as shown in Fig. 1 (a).



Object	Description
ME	Managed network element
EQ	Board
PG	Protection ports group
PTP	Physical terminal point
OptMod	Remote optical module
CTP	Connection terminal point
Connection	Connection
Alarm	Equipment/service alarm
Performance	performance parameter
TCA	Performance out of limit alarm

(c)

Fig. 1 (a) System architecture of semi-active WDM; (b) Management and control architecture; (c) Objects design.

Generally, a network management system uses IP signaling as control signaling to interact with network equipment. However, the optical modules on the AAU side can not support IP signaling. The traditional management and control scheme can only manage and control the active WDM device, but can not directly interact with the remote optical modules.

In order to manage and control the whole semi-active system, the pilot-tone OAM technology is proposed and used for information interacting between the optical modules and the active device. Optical modules setting and getting commands can be converged and forwarded on active device through the pilot-tone OAM. FH-MCS interacts with active device through IP signaling to realize the configuration, query and performance monitoring of active device and remote optical modules

3. Key Technologies

3.1. Abstract Model and Object Design for Semi-active System

The centralized FH-MCS can control multiple sets of semi-active systems, including active WDM device and optical modules. The standardized information model and operation command of the FH-MCS Southbound Interface is proposed.

In general, management and control model only abstracts and manages active devices, excluding remote passive components. Therefore, the traditional modeling scheme cannot meet the management and control requirements of semi-active systems. We abstracted the semi-active system through a unified information model. The defined objects are shown in Fig.1 (c). Fig. 2 (a) shows the system abstract model. The optical module is abstracted by object named OptMod, which is associated with corresponding Och PTP. The OptMod parameters contain basic informations like vendor information, central wavelength and SN number, and performance parameters like bias voltage, temperature and optical power. The FH-MCS Southbound Interface is implemented through NETCONF + Yang. The objects relationship is shown in Fig. 2 (b).

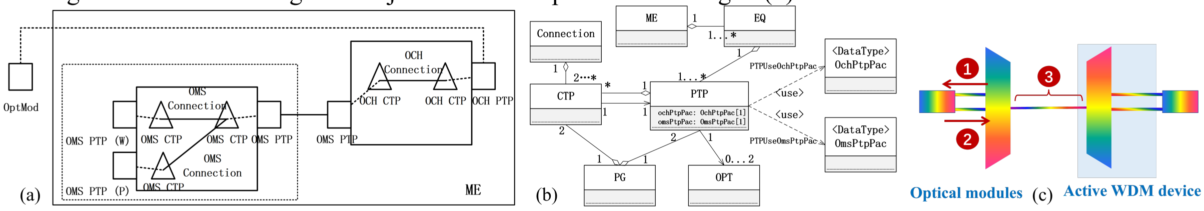


Fig. 2 (a) Abstract model of semi-active system; (b) Objects relationship; (c) Alarm location diagram.

3.2. Pilot-tone OAM

Pilot-tone OAM is proposed in the semi-active system. It can be implemented by using the single frequency modulation or multi-frequency modulation pilot tone based on the low modulation depth of the optical channel signal [6]. By pilot-tone OAM signals, overhead information can be added into optical layer wavelength. The OAM signal analysis module is deployed on the active device side to realize signaling interaction between the remote optical module and the active device.

The frame format of pilot-tone OAM is shown in Fig.3. The length of each frame is 64 bytes, and message body is filled into the fixed length frame with variable length, the idle bytes are filled by ‘0’. This OAM signal can be used to set, get and monitor parameters of optical module.

Flag	Module ID	Message Type	Message ID	Frame Length	Check Code	Message Body	idle	Flag
4byte	1byte	1byte	1byte	1byte	1byte	X bytes (variable length)	Y bytes	1byte

64 byte

Fig. 3. Frame format of pilot-tone OAM

3.3. Function and Application of FH-MCS

Through the collaboration of NETCONF and OAM, FH-MCS can manage and control the entire semi-active system, including active WDM devices and remote optical modules. The management and control functions include device configuration, performance monitoring, switching on/off of laser, loopback and retrieval of optical module's performance.

One of representative a*pplications is that w*hen a fiber fault occurs, FH-MCS can accurately locate the fault based on the alarm information, greatly reducing the troubleshooting process. When the optical module cannot receive optical signals, the module reports ‘LOS’ alarm through OAM. After detecting this alarm, the active WDM device reports the alarm information to FH-MCS through NETCONF. If the active WDM device cannot receive optical signals from a optical module, the active WDM device will report ‘LOS’ alarm from corresponding local port.

Fig. 2 (c) shows the alarm location diagram. By analyzing the received alarms, FH-MCS can distinguish three types of fault location, including the receive direction of the optical module on section ①, the transmit direction of the optical module on section ② and the fiber of section ③.

4. Field Trial of the FH-MCS

In order to verify the FH-MCS, field trial is carried out on China Mobile's network. As shown in Fig.4, the FH-MCS is connected with multiple active WDM devices through the metro DCN over the metro transport network. FH-MCS is deployed in the metro core machine room and active WDM devices are deployed in the DU machine room. The active WDM devices are connected with the optical modules at the AAU side through the pilot-tone OAM channel.

In this experiment, it is successfully verified that the FH-MCS can monitor fixed or dynamic information such as manufacturer, serial number, bias voltage, transmitting optical power, receiving optical power and so on. When the remote optical modules or the active devices are faulty, the corresponding alarm can be received, and the fault location can be marked and warned. The experimental environment is shown in Fig. 4. Fig. 5 shows the interaction process and NETCONF protocol messages between FH-MCS, WDM device and remote optical modules.

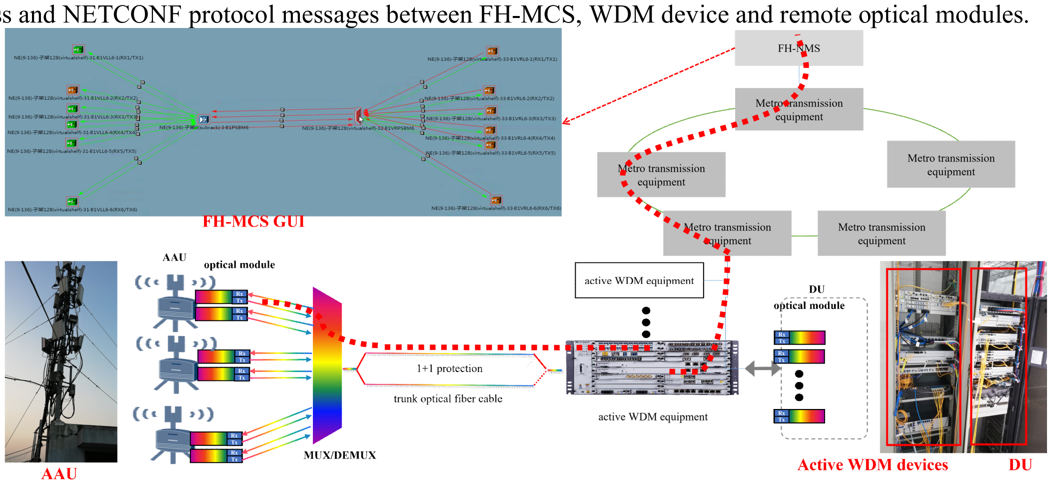


Fig. 4. Field trial experimental environment

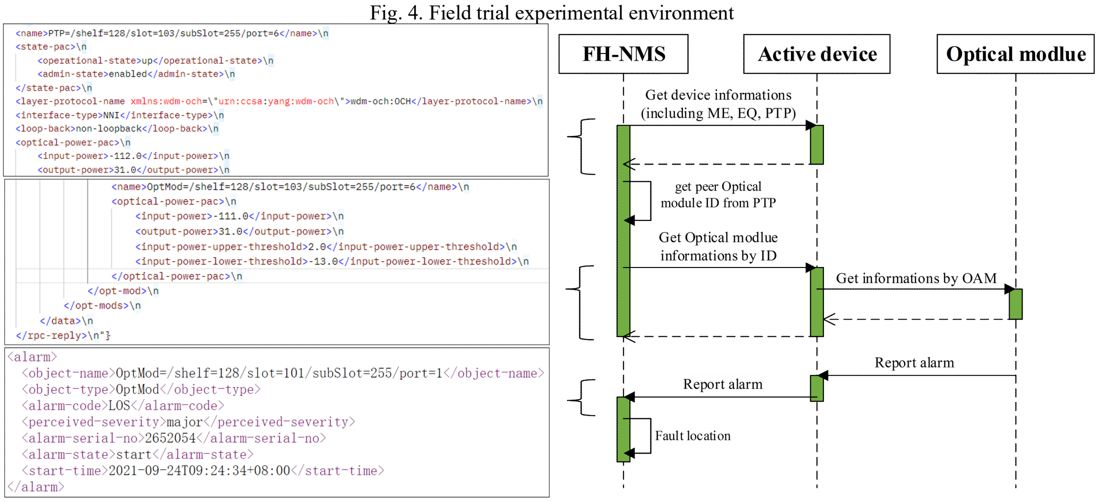


Fig. 5. Interaction process and NETCONF protocol messages

5. Conclusion

In this work, FH-MCS for semi-active WDM system on 5G fronthaul networks is performed experimentally, which can end-to-end manage and control semi-active WDM system. The functions are verified in field trial, including information inquiring, alarm receiving and fault locating. The field trial results show that the FH-MCS can be beneficial to the high reliability of the 5G C-RAN front-haul network.

Yang Zhao and Jiang Sun contribute equally to this article.

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