# Demonstration and Trial of a new CWDM and Circulator integrated semi-active system for 5G fronthual

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**Abstract:** We demonstrate a new CWDM and Circulator integrated semi-active system for 5G fronthaul, and key test data. The system can support 6-channel 25 Gbit/s fronthaul channel capability, and support protection switching function, real-time signal power of multiple working wavelengths Online detection function, and reflected interference signal power detection function.

## 1. Introduction

In recent years, large-scale commercial deployment of 5G communication networks is underway around the world, and many new requirements have been put forward for fronthaul network networking and key technologies. In fronthaul application scenarios, a single base station generally requires 3 fronthaul channels, and the typical interface rate of each fronthaul channel is 25Gbit/s. The fronthaul service carried is generally an Ethernet-based enhance Common Public Radio Interface (eCPRI) data stream [1]. There are many fronthaul technical solutions for deployment, including direct fiber connection based on dual-fiber bidirectional optical modules (OM), direct fiber connection based on single-fiber bidirectional (BiDi) OMs, Coarse wavelength division multiplexer (CWDM), wavelength division multiplexer passive optical network (WDM-PON) [2] and so on. With the development of technologies and application practices, the CWDM scheme is gradually becoming the mainstream which supporting 3 25Gbit/s fronthaul channels based on 6 wavelengths (wavelength grid defined in ITU-T G.694.2 [3], two of them forming a two-way transceiver wavelength pair as a fronthaul channel. Since Directly Modulated Laser (DML) can be used, the CWDM scheme has mature industry chain support and obvious cost advantages.

Given the new deployment scenarios such as 5G network co-construction and sharing, multi-frequency networking (2.1G and 3.5G frequency bands), 4G base station and 5G base station co-location, and rapid growth of mobile network traffic, new demands have also appeared in the fronthaul network. For example, a single base station needs to provide 6 fronthaul channels. And in the industry, some innovative methods are under development and verified.

## 2. A new CWDM and Circulator integrated semi-active system for 5G Fronthaul

In this article, we demonstrated a new CWDM and circulator integrated semi-active system as shown in Figure 1 which consists of Head Equipment (HE) and Remote WDM (RW). The system can achieve a single system 6-channel 25 Gbit/s fronthaul channel capability, and supports protection switching, online detection of signal power at multiple operating wavelengths, and reflected signal power detection function.

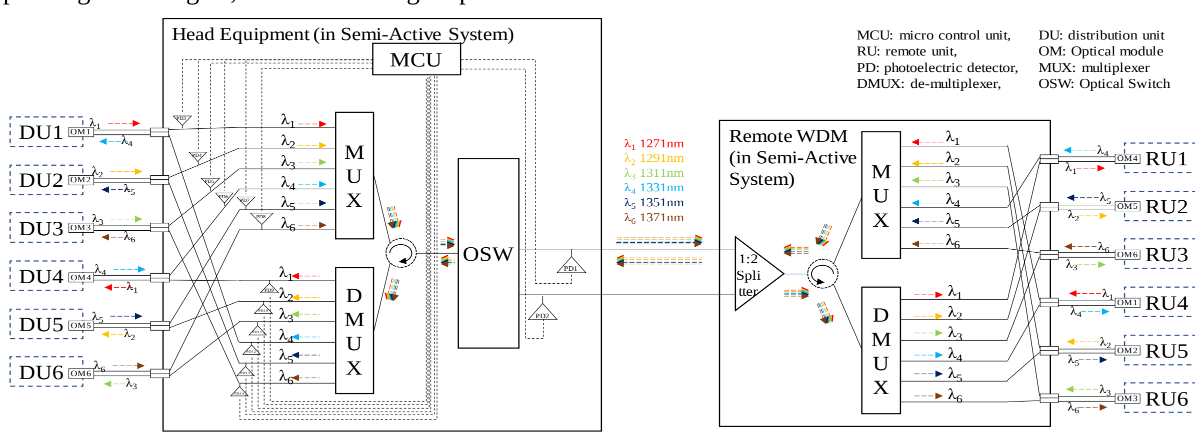


Figure 1 System architecture diagram

The system used the first 6 wavelengths in the CWDM wavelength grid defined in ITU-T G.694.2 [3] (namely, the nominal central wavelengths for spacing of 20 nm are 1271 nm, 1291 nm, 1311 nm, 1331 nm, 1351 nm, 1371 nm) as the working wavelength. Combining multiplexer (MUX) and de-multiplexer (DMUX), the directivity of the optical circulator was used to realize the single-fiber bidirectional transmission of the multiplexed signal in the feeder fiber, and realize the 6-channel 25 Gbit/s fronthaul channel capability. The receiver of each OM in the scheme had gray receiving characteristics, which can receive optical signals of any six wavelengths. Because the same wavelength was selected, the OM in this scheme can reuse the transmitting and receiving components in the CWDM scheme, which can realize the purpose of sharing the industry chain and reducing the overall cost of the system.

An Optical Switch (OSW) and MUX/DMUX were built in HE. A passive coupler was integrated with MUX/DMUX on the remote unit (RU) side to construct RW. The HE and RW were connected by two trunk fibers (one working, and one spare). Protection function was triggered by the monitoring result reported by the corresponding photoelectric detectors (PD1~PD2) attached to trunk fibers. The real-time optical transceiver power detection function, which can accurately locate the fault position, are enabled through the built-in PDs (PD3~PD14) attached to each internal wavelength path.

By inserting the management feature fields based on the amplitude modulation method on the working signals (done in each OM, transmitting rate 100bps, composition of management feature fields shown in Figure 2), it was possible to distinguish the reflected optical signal and the service optical signal and measure the reflected optical power.

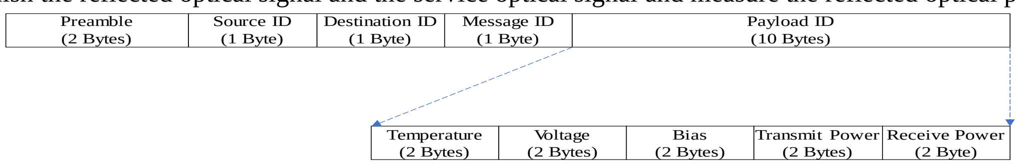


Figure 2 Composition of management feature fields

## 3. Laboratory test results

We tested the key optical layer parameters, as shown in Table 1. The results showed that the system can support 10 km applications, and the power budget exceeds 19.5dB. Different reflection scenarios were simulated by adding multiple connectors in between HE and RW, with results reported in Table 2. The test result of the reflected signal of the system was generally smaller compared to the result of the OPM, with the deviation less than 2.7dB.

Table 1. Key optical layer parameters test results (LAB)

| Wavelength | Transmitted Power (dBm) | Received Power (dBm) | Receiver Sensitivity (dBm) | System Power Budget (dB) |
|---|---|---|---|---|
| OM1 (1271nm) | 3.1 | -7.6 | -18.5 | ⩾ 21.6 |
| OM2 (1291nm) | 4.05 | -8.1 | -18.3 | |
| OM3 (1311nm) | 4.4 | -6.8 | -18.1 | |
| OM4 (1331nm) | 4.4 | -7.1 | -18.5 | |
| OM5 (1351nm) | 4.05 | -6.0 | -18.8 | |
| OM6 (1371nm) | 3.65 | -6.4 | -18.6 | |

Table 2. results of reflected signal measurement (LAB)

| Wavelength | Test Set A (dBm) | | | Test Set B (dBm) | | | Test Set C (dBm) | | |
|---|---|---|---|---|---|---|---|---|---|
| | By OPM | By System1 | Deviation | By OPM | By System1 | Deviation | By OPM | By System1 | Deviation |
| OM1 (1271nm) | -15.06 | -15.46 | -0.40 | -20.16 | -21.18 | -1.02 | -25.08 | -25.04 | 0.04 |
| OM2 (1291nm) | -14.86 | -16.30 | -1.44 | -20.02 | -21.30 | -1.28 | -25.04 | -26.29 | -1.25 |
| OM3 (1311nm) | -15.03 | -17.43 | -2.40 | -20.01 | -22.20 | -2.19 | -25.03 | -25.11 | -0.08 |
| OM4 (1331nm) | -15.07 | -17.69 | -2.62 | -20.05 | -22.31 | -2.26 | -25.09 | -27.15 | -2.06 |
| OM5 (1351nm) | -15.01 | -17.27 | -2.26 | -19.86 | -22.25 | -2.39 | -24.99 | -25.84 | -0.85 |
| OM6 (1371nm) | -15.01 | -16.61 | -1.60 | -20.11 | -22.66 | -2.55 | -25.00 | -25.70 | -0.70 |

The protection switching test was triggered by cutting off the trunk fiber, and the working signal was switched to another trunk fiber. The test was repeated 3 times in total, with results shown in Table 3.

Table 3. Test result of protection switching time (LAB)

| Key Configuration | Switch Direction | Test 1 (ms) | Test 2 (ms) | Test 3 (ms) | Flow direction |
|---|---|---|---|---|---|
| FEC OFF, Test pattern 128 Byte， Traffic Rate 10000000 fps | Working path to Backup path | 0.4563 | 0.1238 | 0.1766 | UNI——>SNI |
| | | 0.1031 | 0.0505 | 0.1995 | SNI——>UNI |
| | Backup path to Working path | 0.1813 | 0.2669 | 0.1872 | UNI——>SNI |
| | | 0.0006 | 0.1036 | 0.0013 | SNI——>UNI |
| FEC ON, Test pattern 128 Byte， Traffic Rate 10000000 fps | Working path to Backup path | 0.1438 | 0.1437 | 0.1438 | UNI——>SNI |
| | | 0.05 | 0.05 | 0.05 | SNI——>UNI |
| | Backup path to Working path | 0.1536 | 0.1539 | 0.1537 | UNI——>SNI |
| | | / | / | / | SNI——>UNI |

## 4. Test result in field trial

A field trail was carried out, to verify the functions and system performance, as shown in figure 3. The wireless side configuration in the field trial was that the 4G base station and the 5G base station were co-sited, and a total of 6 fronthaul networks were required, of which the 4G base station fronthaul network had been deployed, so the CWDM and circulator integrated semi-active system solution was provided for the 5G base station three 25Gbit/s fronthaul channels. The transmit optical power, the received optical power, and the reflected optical power of the 3 working wavelengths on the RU side and the 3 working wavelengths on the DU side were measured, as shown in Table 4.

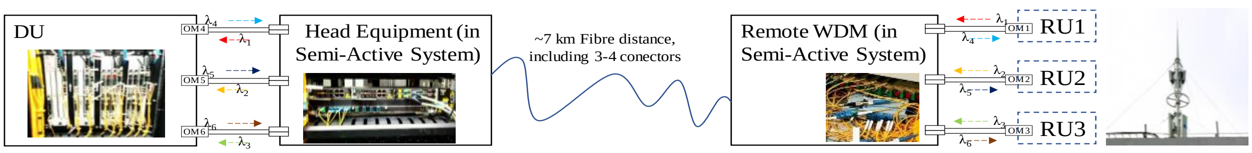


Figure 3 Schematic diagram of test configuration for live network test

Table 4. System optical layer parameters measurement results (Field)

| Optical Module and wavelength | Transmitted Power (dBm) | Received Power (dBm) | Reflected signal power (dBm) | Deployment Position |
|---|---|---|---|---|
| OM1 (1271nm) | 3.27 | -4.65 | / | RU Side |
| OM2 (1291nm) | 3.75 | -4.45 | / | RU Side |
| OM3 (1311nm) | 3.85 | -5.25 | / | RU Side |
| OM4 (1331nm) | 3.06 | -7.30 | -24.247 | DU Side |
| OM5 (1351nm) | 3.55 | -6.00 | -28.270 | DU Side |

## 5. Conclusion

We have demonstrated a real-time CWDM and circulator integrated semi-active system for 5G fronthaul. This system achieved 6-channel 25 Gbit/s fronthaul channel capability based on 6 CWDM wavelengths, realize the optical power monitoring and protection switching function through Tap PD and optical switch. Laboratory test results and field trial results showed that this solution can meet the reliability and operation and maintenance requirements in fronthaul applications. In the future, this solution can further load the amplitude modulation of each optical module to carrier waves of different frequencies, and use two Tap PDs after the circulator to monitor the status of each optical module and reflection, thereby simplifying the system complexity.

## 6. References

[1] CPRI Industry Cooperation, "Common Public Radio Interface: eCPRI Interface Specification" V1.2 (2018-06-25)
[2] ITU-T G.9802.1 (08/21), "Wavelength division multiplexed passive optical networks (WDM PON): General requirements", https://www.itu.int/rec/T-REC-G.9802.1/en
[3] ITU-T G.694.2 (12/03), "Spectral grids for WDM applications: CWDM wavelength grid", https://www.itu.int/rec/T-REC-G.694.2/en