Lambda as a service based on DWDM tunable laser in metro access network

Shikui Shen
China Unicom Research Institute
Beijing, China
shensk@chinaunicom.cn

Guangquan Wang
China Unicom Research Institute
Beijing, China
wanggq122@chinaunicom.cn

He Zhang
China Unicom Research Institute
Beijing, China
zhanghe35@chinaunicom.cn

Yantao Zhou
China Unicom Research Institute
Beijing, China
zhouyt24@chinaunicom.cn

Yejing Zhang
China Unicom Research Institute
Beijing, China
zhangyj2101@chinaunicom.cn

Pengzhen Yang
China Unicom Research Institute
Beijing, China
yangpz8@chinaunicom.cn

Abstract*—DWDM technique is recognized as the most promising solution to increase the fibre total capacity to support the envisioned traffic explosion in operators' network, which has been widely deployed in backbone and metro core and aggregation layer network. Comprehensive full services operators provide wired and wireless services for consumers, through different solutions, such as radio based, IP based, OTN based, PON based. To upgrade the capacity and fibre usage efficiency in metro access layer, port-agnostic DWDM technique based on low cost tunable lasers and wavelength auto-adaption mechanism was specified in ITU-T Recommendation G.698.4 and has been field trialed in China Unicom network for mobile fronthaul and leased line services. lambda as a service(λaaS) and pay as you grow(PAYG) could be achieved. Each end user occupies exclusive wavelength to enjoy the bandwidth without any affects from other users owing to hard isolation by WDM feature. λaaS based on tunable laser, simply the metro network construction and maintenance as only one kind or several kinds of modules are utilized compared to fixed wavelength modules. Furthermore, DWDM transparent transmission could provide low latency and high capacity, which are main requirements for access services. At last, this technique could be easily integrated with other access solutions, including IP based and OTN based, to provide wavelength level services for buildings, campus, and so on.*

Keywords— λ aaS, DWDM, tunable laser, port-agnostic, metro access network.

I. INTRODUCTION

Dense Wavelength Division Multiplexing (DWDM) technique has been deployed in national longhaul backbone networks, regional networks and metro networks core/aggregation layers for several years to provide large pipes for multiple services, with line rates from 10Gbit/s, to 100Gbit/s, and now even to 400Gbit/s. As the rapid increase of bandwidth for end users, low cost DWDM techniques in the metro edge networks become trend for comprehensive full service operators, to increase the utilization of fundamental infrastructure resources, including optical fibres/cables/ducts/central offices, and to reduce the CAPEX and OPEX.

In this paper, lambda as a service (λaaS) based on low cost tunable laser and port-agnostic bi-directional DWDM transmission in metro access networks was introduced and analyzed detailed, the standardization and key techniques were discussed in Part II, typically application scenarios and deployment were discussed in Part III, and the conclusion was in Part IV.

II. STANDARDIZATION AND KEY TECHNIQUES

A. Standardization status

This metro DWDM technique had been specified since April 2014 in ITU-T SG15 as G.metro, promoted by China Unicom and many worldwide other operators. And it was consent and published as Recommendation ITU-T G.698.4 in 2018 with 10G interface[1]. Fig.1 shows the principle block diagram, head end equipments (HEE) was placed in central office (CO), and tail-end equipments(TEE) were placed for end users. Tunable modules were used in both HEE and TEE.

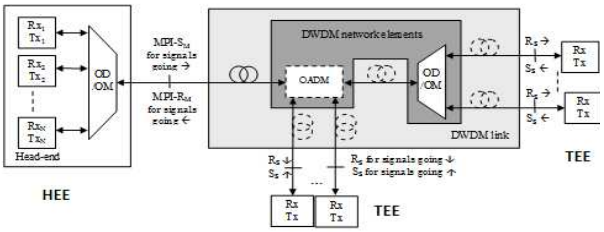


Fig.1 principle block diagram of G.698.4 system

25G interface aiming at 5G fronthaul application had been consent in April 2023 ITU-T SG15 Plenary meeting and published[2].

B. Key techniques and challenges

1) Low cost tunable laser

Low cost tunable laser is the most import and challenging. Tunable laser can be achieved by many ways, including electronic tuning, thermal tuning and mechanical tuning, etc[3]. It has been used widely in high bitrate backbone networks for several years, however, the high cost of tunable laser is the biggest obstacle for metro access layer application. As the the potential amounts of tunable laser in metro access layer application would be huge, therefore the cost of tunable module is much sensitive. Low cost tunable laser is a must in widely metro access application. Currently, cost-effective 10G and 25G tunable laser are developed and demonstrated by several vendors for metro access application, including full C band tunability (more than 30nm) and partial C band tunability (about 5-10nm).

With wavelength tunable modules, the module types in the metro access networks could be unified and simplified, avoiding too many module types and too many modules

Partly supported by National Key R&D Program of China(Grant No.2022YFB2804100).

amounts for spare in maintenance, compared to fixed wavelength modules.

2) Message channel for control and management

Currently, the wavelength of tunable laser used in high bitrate backbone networks are configured manually through network management system (NMS), however, it is not applicable for metro access layer, as the access layer network equipments amounts are almost ten times or hundreds times of backbone networks equipments, configuring wavelength one by one would be disaster for the network maintenance. Therefore, for application in metro access layer, just wavelength tunability is not enough, wavelength self-adaption mechanism are also required.

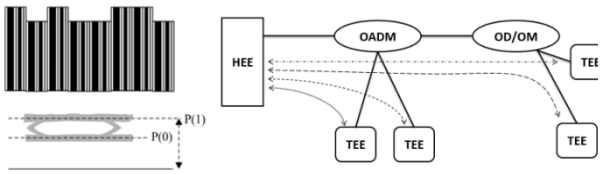


Fig.2. message channel for control and management

In the G.698.4 specified system, message channels (MC) between HEE and TEE, implemented based on low modulation index amplitude modulation imposed on service signals, with bitrate of 50kbit/s, shown in Fig.2, are used as the system control and management channel. The target frequency/wavelength information is transmitted to TEE through MC from HEE, the target TEE could tune its output wavelength to corresponding wavelength without any effect on other channels. And the MC could also transmit the OAM information between HEE and TEE, especially the performance, including digital diagnostic monitoring (DDM) information of tunable modules, warnings and alarms in TEE. The manageability of remote sites are achieved and very helpful for network maintenance.

3) Bidirectional and transparent transmission

Bidirectional transmission could save half fibres, and also avoid asymmetry of synchronization and latency. The wavelength pairs is provided in table.1

Table.1 wavelength pairs for bidirectional transmission

wavelength pairs	wavelength for HEE to TEE (nm)	wavelength for TEE to HEE (nm)
1	1529.55	1550.12
2	1530.33	1550.92
3	1531.12	1551.72
...	...	...
19	1543.73	1564.68
20	1544.53	1565.50

Transparent transmission without electronic processing could avoid effect on the signal performance, and also the extra latency. Low latency and high synchronization is quite important for 5G fronthaul application.

4) SDN control and management

For metro access layer application, open and disaggregated networks are trend, therefore, equipments from different vendors are utilized for operators' metro network. Through SDN controller and Netconf southbound interface (SBI), the G.698.4 systems from different vendors for different application scenarios could be managed by operators' own SDN controller system, which could simplify the network operation and maintenance greatly, Fig.3 shows the example of YANG tree.

```
+--rw och-ptp-pac
   +--rw frequency?          acc-type:real
   +--rw pilot-tone?         acc-type:real
   +--rw peer-fequency?      acc-type:real
   +--rw channel-no?         int32
   +--rw lambda?             acc-type:real
   +--rw channel-space?      int32
   +--rw optmod-type-name    optmod-type-name
   +--rw hee-pac
      +--ro tee-device-cpu?            boolean
      +--ro tee-device-mac?            string
      +--ro tee-device-sn?             string
      +--ro tee-device-software?       string
      +--ro tee-device-hardware?       string
      +--ro tee-board-name?            string
      +--ro tee-line-ptp-name          -> /acc-devm:ptps/ptp/name
      +--ro tee-client-ptp-name?       -> /acc-devm:ptps/ptp/name
      +--rw tee-opt-mod-type-name?     optmod-type-name
      +--rw tee-line-loopback?         acc-devm:loopback-type
      +--ro tee-line-opt-mod-type      acc-devm:opt-mod-type
      +--ro tee-client-opt-mod-type    acc-devm:opt-mod-type
      +--rw tee-client-signal-type?    identityref
      +--rw tee-line-ddminfo-pac
      |  +--ro input-power?    acc-type:real
      |  +--ro output-power?   acc-type:real
      |  +--ro temperature?    acc-type:real
      |  +--ro bias-current?   acc-type:real
      |  +--ro voltage?        acc-type:real
      +--rw tee-client-ddminfo-pac
      |  +--ro input-power?    acc-type:real
      |  +--ro output-power?   acc-type:real
      |  +--ro temperature?    acc-type:real
      |  +--ro bias-current?   acc-type:real
      |  +--ro voltage?        acc-type:real
      +--rw tee-line-vendor-pac
      |  +--ro opt-mod-vendor-name?   string
      |  +--ro opt-mod-vendor-pn?     string
      |  +--ro opt-mod-vendor-sn?     string
      |  +--ro opt-mod-vendor-rev?    string
```

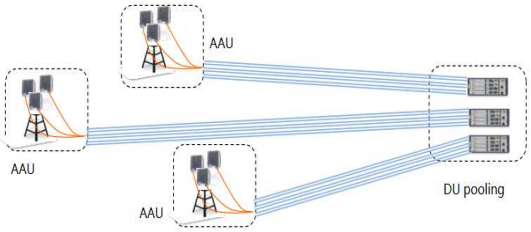
Fig.3. YANG tree example of G.698.4 system

III. APPLICATION SCENARIOS AND DEPLOYMENT

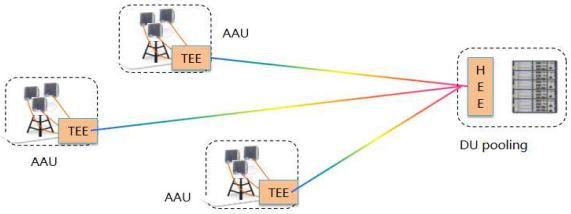
DWDM lambda based optical connections had several advantages, including the high capacity with 20x10G/25G, hard isolation pipe using wavelength, which could be used in different metro application scenarios, include mobile fronthaul and leased line services.

A. Mobile fronthaul

To reduce the centre offices and upgrade wireless performance, cloud radio access networks (C-RAN) mode had been deployed widely since LTE era, several baseband units (BBU) were centralized, even dozens of or hundreds of BBUs, especially in northern China Unicom. Currently, dedicated fibres are the main solutions for LTE and 5G fronthaul, which would consume huge amounts of fibres. For examples, six fibres are need for each S111 station with three sectors, shown in Fig.4(a). Therefore, WDM techniques are considered as the candidate solutions for fronthaul to save fibres, including coarse WDM(CWDM), LAN-WDM, MWDM and DWDM. Compared with other WDM techniques, DWDM has great advantage of system capacity using 100GHz channel spacing.



(a) dedicated fibres solution

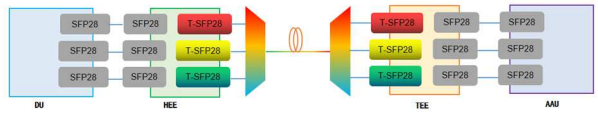


(b) DWDM based solution

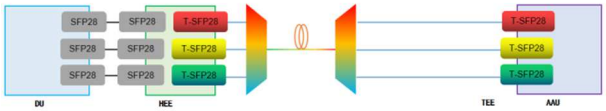
Fig.4 fronthaul connections

With G.698.4 DWDM solution based on tunable laser with enhanced feature of port-agnostic in 5G fronthaul, just single fibre could connect 3 AAUs of 5G, shown in Fig.4(b), meanwhile 3 RRUs of LTE in the same station. Otherwise,12 fibres would be need for LTE and 5G fronthaul together if dedicated fibre solution used.

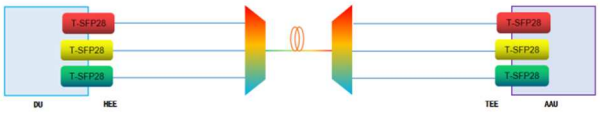
According to the HEE and TEE equipments types, there are three deployments in mobile fronthaul application, i.e. active HEE co-located with DU pooling in centre office, and active TEE co-located with AAU in remote sites(tower, pole, etc), shown in Fig.5(a), active HEE and enhanced tunable module directly installed in AAU, shown in Fig.5(b), voiding the extra installation and power supply of TEE, especially for outdoors; both enhanced tunable modules directly installed in DU and AAU, shown in Fig.5(c).



(a) active



(b) semi-active



(c) passive

Fig.5. three deployments in fronthaul

Semi-active 25G application for 5G fronthaul had been field trialed in Jiangsu Province and Guangdong Province of China since 2021, and the equipments of Jiangsu trial are shown in Fig.6.

(a) HEE co-located with BBU in CO

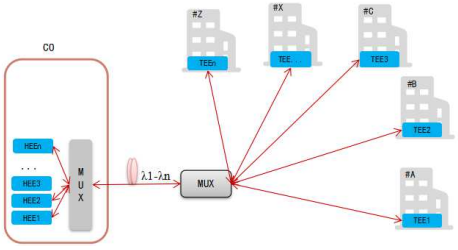
(b) TEE tunable module in RRU

Fig.6. semi-active deployment trail

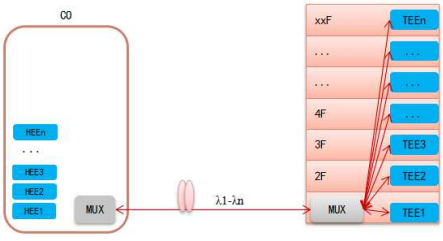
B. *Leased line services*

With deep implementation of Broadband China strategy over the country, the bandwidth demands for leased line services are increasing simultaneously, from existed several or dozens of Mbit/s to hundreds of Mbit/s, even up to 1Gbit/s and 10Gbit/s. Especially, as rapid development of cloud based network architectures and services, the bandwidth access to cloud and computing power will be even larger, which is the main drive for leased line services.

As shown in Fig.7(a), the different buildings could be connected through wavelengths to central office, to achieve all-optical campus. For large bandwidth demand business buildings, the end-users in every floors could be connected through wavelengths to achieve all-optical buildings, shown in Fig.7(b). Passive MUX is utilized to router wavelengths covering different end-users, just like PON networks using optical power splitters.



(a) lambdas to the buildings



(b) lambdas to the floors

Fig.7. wavelength connections for leased line services

Furthermore, owing to WDM technique, the bandwidth per wavelength or wavelengths occupied per user could be upgraded easily as the bandwidth requirement grown, which means pay as you grow(PAYG). Furthermore, this technique could be easily integrated with other access solutions, including IP based solutions and OTN based solution, to provide wavelength level services for buildings, campus, and so on.

10G interface customer premise equipment(CPE) based G.698.4 system had been commercially deployed in China Unicom since 2021 for large bandwidth demand leased line service. The typical application is shown in Fig.8, where 1+1 protection is deployed, using 3dB splitter in TEE and optical switch in HEE through two different trunk cables and optical cross connection cabinets(OCC) for high reliability.

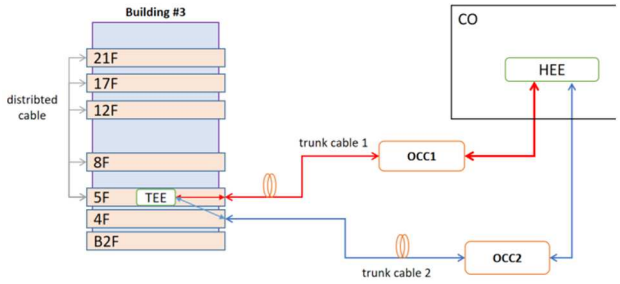


Fig.8. leased line service with 1+1 protection

ITU-T G.698.4 is the most promising solution for metro access networks for comprehensive full-service operators. It could served as ultra broadband metro integrated service access solutions, and based on DWDM, it could realize wavelength to the antennas, enterprises, residential, server, etc. It had been verified through the field trials in 5G and metro application.

REFERENCES

[1] Recommendation ITU-T G.698.4 (03/18): Multichannel bi-directional DWDM applications with port agnostic single-channel optical interfaces. https://www.itu.int/rec/T-REC-G.698.4-201803-I/en

[2] Recommendation ITU-T G.698.4 (06/23): Multichannel bi-directional DWDM applications with port agnostic single-channel optical interfaces. https://www.itu.int/rec/T-REC-G.698.4-202306-P/en

[3] Jens Buus and Edmond J. Murphy, Tunable Lasers in Optical Networks, IEEE Journal of Lightwave Technology, Vol. 24, No. 1, pp. 5-11, Jan. 2006.