Coarse WDM in Metropolitan Networks: Challenges, Standards, Applications, and Future Role

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Abstract. Coarse Wavelength Division Multiplexing (CWDM) denotes a technology of diaphanous transport which aids to transmit simultaneously a large number of services across a single optical fiber. This technology relies on the usage of optical channels which are 20 nm from each other. These channels are employed in the CFO OPX products, which ranged from 1270 nm until 1610 nm, had been set in ITU-T G-694.2 recommendations. ITU-T managed to determine 18 optical channels together, though 16 only are used in reality, in the case of using the two lowest channels which are avoided because of the excessive-high attenuation of glass. However, the review study presented in this paper deals with the CWDM technique as the best choice in decreasing capital expenditure after taking into consideration the simplicity of design, the capability of expanded transmission, low cost of components and reduction in operational cost. The paper also focused on the standards, applications and future role of the CWDM technique.

Keywords: CWDM, Fiber-Optic, WDM, DWDM, CFO OPX, ITU-T.

1. Introduction

Wavelength-division multiplexing (WDM) denotes a technology utilized in fiber-optic communications which multiplexes several optical carrier signals in a single optical fiber by utilizing laser light of various wavelengths [1]. WDM method facilitates two-way communication using fiber besides increasing its volume. Figure 1, displays a WDM system that utilizes a multiplexer at the transmitting end to connect together the signals and a demultiplexer at the receiving end to rip the signals. Using the correct form of fiber will enable a gadget to carry out both functions at the same time besides functioning as an optical add-drop multiplexer[2]. This idea initially announced in the year 1978 and WDM systems were already tested in research labs by 1980. Since it is an idea that involved a system, the WDM includes both (CWDM) and (DWDM) [3]. The current study concentrates more on CWDM[4].
However, the WDM system involves every regulated signal that needs to be conveyed at a specific frequency, thus enabling transmission of full-duplex data. WDM systems divide the bandwidth of the fiber that is available into different channels whereby every channel will carry a signal. Hence, the whole total data rate is increased by not adding the fiber quantity. Each channel can limit the data rate. However, many channels will contribute to the total data rate to be significantly higher [5]. At the receiving end of the connection, a de-multiplexer is utilized to separate the wavelengths and channel them into different fibers enabling them to end up at different receivers [6].

Coarse WDM and Dense WDM are determined based on the space amid the specific wavelengths which are conveyed by the same fiber. As a cost-saving measure to fulfill their transport requirements, Coarse WDM is readily acknowledged as vital transport architecture. Since Coarse WDM systems are available commercially, this technology provides advantages that enable it to be a viable substitute to Dense WDM in many access applications and metros [7].

The Coarse WDM system was not popular as it could not create substantial interest amongst service providers. However, the development of Erbium Doped Fiber Amplifiers (EDFA) which has larger bandwidth has made this method popular [8]. As for multi-wavelength signals, EDFA can strengthen a many optical signals which can be multiplexed into its amplification band provided it has enough pump energy [9]. This characteristic of EDFAs also allows the usage of the Dense WDM (DWDM) method that utilized denser channel spacing to attain an even higher bit rate [10].

2. Challenges of CWDM

CWDM network inspection difficulties are primarily in three stages: construction and configuration, device deployment, and upgrading or troubleshooting.

2.1 Construction and Installation

Physical-layer tests must be done on the fiber during the development and establishment stages from the head-end to the goal, either an end-client or a phone tower, and the other way around. Single-finished testing, e.g., with an OTDR, is a bit of leeway since it advances work assets. In such a case, For this situation, the point is to describe the entire connection (not simply the fiber) to incorporate the include drop multiplexers (OADM) and to guarantee progression to the last goal [11]. Testing at standard OTDR wavelengths, for example, 1310 nm and 1550 nm, can regularly not be completed under conditions, for example, sifting through these wavelengths at either OADM, never arriving at the last goal.

2.2 System Activation

Since CWDM network architecture is rather basic, which does not contain active components such as amplifiers, transmitter failure is the only thing that can prevent proper transmission in a CWDM network system. A sudden change in OADM loss or manual errors, such as bad connections. In order to deal with these issues, the signal being transmitted must be looked at [12].

2.3 Upgrade or Troubleshoot

When the network is live, and a new wavelength is added or one of the receiving parties experiences problems (maintenance and troubleshooting), a final challenge comes up.

3. Related Works

S. Robinson, et al. (2015) [13] proposed a hybrid WDM system. System parameters, for example, bit mistake rate (BER), quality factor and affectability of the collector are investigated for the association separation for various climate conditions. 4 CWDM and 8 DWDM channels are viewed as whose comparing channel dispersing is 20nm and 0.8nm, individually. In view of that, It guaranteed that the normal connecting separation of the proposed WDM/FSO cross breed framework for DWDM and CWDM is around 810 km and 780 km. The proposed half and half WDM-based FSO conspire is planned to oversee transmission unwavering quality for 12 customers, each with a 2.5Gbps information rate.

K. Venkatachalam, et al. (2016) [14] have presented a four-channel demultiplexer which is designed using the two-dimensional photonic crystal for Coarse Wavelength Division Multiplexing applications. Their demultiplexer proposed consists of a bus waveguide, a wave output guide, and a cavity. A cavity with a unique refractive index is used to select the channel. The two-dimensional finite time domain and
plane-wave expansion methods are used to estimate the proposed demultiplexer's standardized spectrum and bandgap. The proposed demultiplexer's footprint is about 129.96μm² which is very low and is therefore appropriate for integrated photonic circuits.

Norshamsuri Bin Ali, et al. in (2017) [15], Several distinct features of the conventional CWDM scheme were provided. One is the channel spacing by which the channel spacing is lower relative to the normal scheme. The scheme utilizes a broad spectrum of laser sources. Before transmitting, the source is filtered using 'Bragg Grating.' The filtration provides greater OSNR than conventional CWDM configuration. It has been discovered that the scheme can convey up to 2.5 Gbps through each line with 10-12 failure probability for the data rate of 155 Mbps, the highest range that this scheme can support is about 27 km.

J. C. Mikkelsen, et al. (2018) [16] have exhibited a polarization heartless silicon nitride (isn) 4-channel wavelength demultiplexers dependent on utilizing interferometer grid channels for CWDM in the O-band which are shown in an (isn)-on-silicon photonic stage. The addition misfortune for the best performing gadget was under 2.8 dB, the between channel crosstalk was not exactly - 11.5 dB for a polarization mixed of the information, and the passband move between the symmetrical polarizations was under 1.5 nm. The bite the dust found the middle value of addition misfortune and greatest crosstalks over the 200mm wafer were 3.1 dB and - 10.6 dB, separately. Because of size contrasts, the crosstalk was higher than anticipated. The work indicated the potential for CWDM without the polarization assorted variety of SiN photonic circuits[17].

4. Theory of CWDM

CWDM equipment can carry out two functions, namely: (a) segregate the light to determine only the preferred wavelengths combinations are utilized. (b) multiplex and de-multiplex a signal through a single fiber link[18]. Generally, CWDM offers 8 wavelengths abilities ranging from 1470nm to 1610nm, each 20nm apart that enables the transmission of 8 customer interface using similar fiber, as illustrated in Figure 2. CWDM possesses the ability to transport a maximum of 16 wavelengths or channels in a spectrum framework ranging from a 1270 nm to 1610 nm with a channel space of 20nm [19]. Every channel can function either at 2.5, 4, or 10Gbit/s. CWDM has not amplified the wavelengths of transmitted data as the majority of the channels fall out of the operating window of the erbium-doped fiber amplifier (EDFA) utilized in DWDM[20]. This causes the overall system reach to be shorter to roughly 100 kilometers only. Nevertheless, since CWDM has broader channel space, less expensive un-cooled lasers are utilized. Thus, providing a cost-saving benefit over DWDM systems[21].

![Figure 2: The CWDM system](image.png)

Many organizations utilized CWDM as the admittance level because of its low cost. Each CWDM wavelength can support until 2.5Gbps, which may be extended to support 10Gbps. This transfer rate can
support Fast Ethernet, GbE, or 1/2/4/8/10GFC, STM-1/STM-4/STM-6/OC3/OC12/OC48 and others [22].

CWDM is a preferred technology for cost-saving transportation of a large quantity of data trafficking in telecommunication services or other organization's networks. Optical networking, mainly CWDM technology, has been verified as the most cost-saving method to address this prerequisite[4].

5. CWDM standards

5.1 ITU CWDM wavelength grid

Metro CWDM technology consists of uncooled lasers with 20 nm space and optical filters. Currently, 18 wavelengths identified by nominal wavelengths, which range from 1270 nm till 1610 nm are available. The plotting of ITU-T G.694.2 CWDM wavelength grid into the O, E, S, C and L bands are displayed in Figure 3[23]. Figure 3 also shows a normal attenuation curve for the base installed for ITU-T G.652 fiber, for example, OFS Conventional fiber and Corning SMF-28. The plotting of CWDM wavelengths on the fiber attenuation curve illustrates better clarity besides highlighting several wavelengths, for example, E-band, which incurs a higher loss in fibers of this kind [24].

![Figure 3. A plotting of ITU-T G.694.2 Metro CWDM Wavelength](image)

5.2 First metro CWDM implementation

The CWDM wavelengths that are in the E-Band are displayed in Figure 2. Normally E-band will not be utilized on G.652 standard kind of fiber because of water peak. Although the decrease caused by water peak is normally not much at 0.5dB/km, the maximum loss can reach 2dB/km or higher[25]. Customers will not risk purchasing products that might not function with several or all metro G.652 type fiber. Hence, the initial items which use and set up CWDM in most optical metro applications only concentrate on band C, O, S, and L [9]. The Optical metro applications that used the O-Band for 1310 nm transport service have an option to abandon this particular band unutilized and include new volume to the pre-existing fiber through the 8 CWDM wavelengths in the L and C bands. In order to achieve this objective, the initial CWDM filters and lasers which were designed to fulfill the developing ITU-T G.694.2 standard have been created for 8 CWDM wavelengths ranging from 1470 nm to 1610 nm [26].

Moreover, the fiber attenuation for this section is close to or at the minimum that is required to maximize the quantity of Optical Add/Drop Multiplexer (OADM) nodes and/or the transmitting space between the optical regenerators. The CWDM transmitters for this section could utilize lasers with higher powers than the O-band ones and fulfill the requirements of Class One Eye Safety Precautions. As for the O-Band, several 1310 nm transport services have been identified. For instance, the present SDH/SONET or new IEEE 802.3ae 10 Gigabit Ethernet (10 GbE) services [9].
5.3 IEEE 10GbE standard
The 10GbE standard can bolster different Physical-Layer (PHY) Media Dependent sub-layer decisions in the O-Band. The 10GBaseLX-4 standard for the 1310 nm window depends on the CWDM LAN investigate did in the center to-late 1990s. At the outset, the decision of a 10GBaseSX-4 CWDM was suggested for the 850 nm window. A few items that used this alternative are accessible. The 10GBaseLX-4 standard design is shown beneath[27].

5.4 10GBaseLX-4 standard
This standard is almost the same as ITU CWDM standard, but the wavelengths have 24.5 nm space in between and are known as Wide WDM (WWDM). This standard was invented to enable the fiber-optic base cabling installed on campuses and buildings to be utilized for 10GbE[28]. Hence, it can be utilized by single and multi-mode fiber cables that may face a problem of excessive dispersion at 10Gbit/s serial line rates. As an alternative, four wavelength lanes or channels each one at 3.125 Gbit/s in the O-Band are as stated below. The distance of transmission is identified as 10 km. However, several industrial WWDM gadgets can achieve 20 km [29]. Channel (0) from 1269.0 to 1282.4 nm (1275.7 nm / nominal), Channel (1) from 1293.5 to 1306.9 nm (1300.2 nm / nominal), Channel (2) from 1318.0 to 1331.4 nm (1324.7 nm / nominal), Channel (3) from 1342.5 to 1355.9 nm (1349.2 nm / nominal).

5.5 OIF VSR-5
The Optical Internetworking Forum (OIF) reported on January 2002, the prerequisites of a Very Short Reach (VSR) Level 5 interface for Intra Office (CO) and customer interconnectivity at OC-768 (40 Gbit/s) rates. Different decisions have been proposed, for example, 4 x 10 Gbit/s CWDM over a solitary mode fiber in the O-Band (1310 nm)[30].

6. CWDM standards convergence
Proposals were submitted to the ITU for the IEEE 10GBaseLX-4 and OIVSR-5 wavelength to be utilized for ITU CWDM standard. The first choice is to replace the pre-existing 5 wavelengths known as ITU-T G.694.2 which has 20 nm spacing in the O-Band with 4 wavelengths known as IEEE 10GBaseLX-4 with 24.5 nm spacing. This resulted in 17 instead of 18-CWDM wavelengths. These (17) wavelengths can be utilized. for instance, in 16 user-channels and high-speed Optical Supervisory Channel (OSC)[19].

Merging the LAN WWDM and Metro CWDM standards can bring about an extra reduction in the cost of the systems and components. There are no disadvantages linked to a single, converged CWDM standard other than one CWDM channel, which is almost useless that will be lost [31]. The Small Form-Factor Pluggable (SFP), Cisco Coarse Wavelength-Division Multiplexing (CCWDM), Gigabit Interface Converter (GBIC) solution enables service providers and organizations to offer accessible and easy-to-deploy Fibre Channel services and Gigabit Ethernet in their networking. The product set allows flexible designing of readily obtainable multi-service networking as show in figure 4.

Combining the LAN WWDM and Metro CWDM models can realize an additional decrease in the expense of the frameworks and parts. There are no hindrances connected to a solitary, combined CWDM standard other than one CWDM channel, which is practically pointless that will be lost [31]. The Small Form-Factor Pluggable (SFP), (CCWDM), Gigabit Interface Converter (GBIC) arrangement empowers specialist co-ops and associations to offer open and simple to-convey Fiber Channel administrations and Giga bit Ethernet in their systems administration. The item set permits adaptable planning of promptly possible multi-administration organizing.[33].
7. **THE FUTURE ROLE OF CWDM**

There is now a chance to install the latest fiber technology ITU-T G.652.C. It greatly removes the water limit at 1383 nm and therefore activates the E-band for further expansion of power. OFS and Corning both have fiber goods that meet with this requirement on the market. For broadband metro applications, multiplexer devices with usually 16 CWDM wavelengths are now emerging [34]. Moreover, For a direct balanced, an ease CWDM lasers with a piece paces of up to 2.5 Gbit/s are advanced. The plan depends on the demonstrated of laser innovation from the DFB. DFB innovation has the benefits of a wide line-width with unequivocally smothered side-modes. Along these lines, offering comparable low scattering yield to DWDM straightforwardly tweaked lasers [35].

likewise, their uncooled nature brings about the low power, minimal effort, and little space advantages of CWDM lasers. It guarantees they don't have enormous warmth sinks, control circuits or Thermo-Electric Coolers (TECs) close to the laser chip that spares electrical power and space. For minimal effort CWDM lasers, the run of the mill optical yield intensity of 1mW (0dBm) is accomplished. The CWDM transmission framework has been intended to be less precise to fabricate the CWDM laser wavelength and temperature float than the CWDM data transfer capacity channel. All the more explicitly, G694.2 prescribes a gatekeeper band equivalent to 33% of the channel separating for CWDM filters, which implies a distance of 20 nm. The available range of the filter should not reach 13 nm, and therefore the CWDM laser wavelength can not differ from the average middle wavelength by more than 6.5 nm [4]. DFB laser wavelengths range between 0.08 nm/ ° C and 0.12 nm/ ° C for their average produced frequency. Lasers should be defined to work over the temperature range of telecommunications-grade equipment at least: 0 ° C to + 70 ° C. If a laser is chosen from a bin at its marginal wavelength (e.g. 1550 nm) at the midpoint of the defined temperature range (+ 35 ° C), then over a spectrum from 0 ° C to + 70 ° C. The wavelength may be as adjustable as ± 4.2 nm. This means that the maximum production tolerance on the nominal wavelength of a CWDM laser is ± 2.3 nm to stay within the filter's 13 nm bandwidth. This is relatively small but not as large as a DWDM laser's resistance [36].

7.1 **CWDM Filter**

The engineering of di-electric thin film filter (TFF) is used to minimal effort CWDM channels. The necessary channel qualities (focus wavelength, channel transmission capacity swell stature, absence of entrance, skirt-width, and neighboring channel separation) are altogether cultivated by managed testimony on a glass substratum with optical layers of various refractive record dielectric content. Subsequently, CWDM channel costs are currently controlled by the aggregate of optical layers expected.
to execute them. At last. The smaller the size of the wavelength, the more noteworthy the quantity of optical layers and the better the accuracy required to meet the layer's thickness details[37].

Consequently, For fewer layers in the filter design, CWDM filters are generally less costly. Metro DWDM products typically require over 100 layers for a 200 GHz filter model, while Metro CWDM products also need 50 layers for a 20 nm filter. The outcome is shorter generation time, less materials and higher creation yields for CWDM channels. Thus, the expense of CWDM channels is commonly under half of the expense of practically identical DWDM channels [38].

7.2 CWDM Transmitters
A. The area filled by a laser transmitter from DWDM is around 8 times the size of a laser transmitter from coaxial CWDM.
B. A DWDM transmitter absorbs around 20 times the energy a CWDM transmitter consumes. The CWDM transmitters use roughly for a sixteen-channel WDM network. 4 Watts, whereas the same feature can absorb more than 80 watts in a DWDM model.
C. The CWDM laser transmitter is less expensive because of the above problems. As a result, DWDM transmitter components typically represent 4-5 times their CWDM counterparts ' costs [39].

8. Main features of CWDM
In general, it can be summarized the overview of CWDM in the terms of its main features as follows :

- It’s a cost-effective application that combines relaxed laser wavelength tolerances, uncooled single-mode lasers, and wider passband filters.
- A reach of (90 km) for (2-way) channels at rates of 1.25 Gigabit/second on a single fiber.
- A reach of (55 km) for (8-channels) at 2.5 Gbit/s.
- A reach of (42 km) for (6-way) channels at 1.25 Gbit/s on a conventional single fiber.
- A reach of (42 km) for (16 channels) at 2.5 Gbit/s utilizing low water peak fiber.
- It’s among the newest ITU spec G.694.2, which identified 18 wavelengths in 5 bands with a space of 20 nm and a capability of (50 Mb to 2.7 Gb).

9. Advantages and Disadvantages of CWDM
The overview of the study gave a concise understanding to summarize the advantages and disadvantages of using CWDM as follows:

| Advantage | Disadvantage |
|-----------|--------------|
| - Power consumption can be lower by 20 percent. | - CWDM capacity is less than DWDM. |
| - The space requirement of CWDM is smaller by 30 percent. | - CWDM range is lesser than DWDM |
| - CWDM can use either MMF or SMF cable. | - Amplification vs. Regeneration. |
| - CWDM can utilize LASER or LED power. | - IN CWDM O, A, and M are not carrier class. |
| - For CWDM individual payload per channel is larger. | |
| - It uses cheaper and smaller wave filters. | |
| - CWDM is cost-efficient on startup and expansion. | |
10. Applications

Apart from the various solutions provided by CWDM as mentioned in the earlier sections, the CWDM procedure is highly flexible and has been adapted in specialized applications, for instance:

1. It is used as video headed feed for multiple protocol signals
2. Used for LAN facilities on campuses
3. It has a low volume capacity
4. CWDM is usually distributed and expanded in metro areas
5. It can be used as a route for data center storage
6. DWDM systems spur routes
7. It is applicable whereby low startup and expansion occurs compared to substitute DWDM choices
8. Early WDM technologies are illustrated below

A fiber pair with a separated transmitter and receiver is normally utilized in CWDM applications to facilitate multiple users by allocating a particular wavelength to a client. This procedure starts at a hub, central office (CO), or head end (HE) whereby specific signals at unmistakable wavelengths are multiplexed or joined into a fiber for transmitting downstream [40]. The multiplexing task is accomplished utilizing an aloof CWDM multiplexer (Mux) module, which utilizes a progression of channels with a specific wavelength. These channels are participated in arrangement to interface certain wavelengths into a solitary fiber for transmitting to the field. Outwardly, plant a CWDM demultiplexer (DMux) module which is mostly a reflection of the Mux is used to draw in specific wavelengths from the feeder fiber to be disseminated to a specific FTTX application[41].

Moreover, CWDM which is fit to be used in metropolitan applications can be utilized in cable television networks whereby a variety of wavelengths are utilized for the upstream and downstream signals. The wavelengths utilized in these systems are usually disjoined, for instance, the downstream signal maybe at 1310 nm, but the upstream signal is fixed at 1550nm[42]. Moreover, CWDM is utilized in fiber switches and network interface devices to link multiple fiber lines from the switch over one fiber. CWDM is enhanced for a cost-saving budget whereby a low cost, small power laser transmitter enables deployment to meticulously match assured revenue streams [43].

11. Discussion

CWDM is unlike the traditional WDM and DWDM in utilizing a wider channel space to permit less complicated and low-cost designs of transceivers. To allow 16 channels on a single fiber CWDM requires the whole frequency band between the 1310 nm (second) and 1550 nm (third) transmission window that includes not only the minimum attenuation window and minimum dispersal window but also the key sections whereby OH scattering might take place. At the moment, CWDM technology utilizes a space of 20 nm (3000 GHz) up to 18 channels. CWDM is a choice technology for cost-saving transportation of large quantities of data traffic in organization networks or telecoms. CWDM functions as the optimal and cost-saving method for fulfilling such a demand.

Normally in a spectrum grid, CWDM is able to transport up to 16 wavelengths or channels that range from 1270 nm to 1610 nm with a channel space of 20 nm. Every channel can function either at 2.5, 4 or 10 Gbit/s. The majority of these channels are out of the enhancing window of the Erbium-Doped Fibre Amplifier (EDFA) utilized in the Dense Wavelength Division Multiplexing (DWDM) systems. Thus, CWDM cannot be amplified.

This will lead to a reach of about 100 kilometers, which is a shorter overall system. Nevertheless, low-cost un-cooled lasers are utilized in CEDM and therefore, it has a cost-saving benefit over other DWDM systems. The technologies employed by both DWDM and CWDM are utilized by Trans-mode to transport numerous types of services, for instance, SONET/SDH, Ethernet and Fibre Channel (FC) in metro area networking. Among the two WDM variants, CWDM is the most cost-saving but has limitations in terms of total channel count and distance the traffic is transported. Transmode CWDM solutions can support until 100 kilometers. Both Transmode's TS-Series and TM-Series products are DWDM and CWDM agnostic. This reveals that a CWDM networking can firstly be set up using either one of the product series and then be upgraded to a hybrid DWDM - CWDM network when needed by utilizing pluggable optics and common cards. Hence, the utilization of Transmode's DWDM
or CWDM centered solutions allows the potentially cheapest cost per day without wasting the network scalability.

CWDM technology is expected to develop into a more specialized application to keep up with global development, such as a combination of optical routers and transports or switches that have been created. Moreover, add-on CWDM cards have been included in many transport devices as the cost is low as the manufacturers are continuing to increase capacity and reduce costs. Furthermore, many chances are available for 10G to be developed and deployed to organizations, industries, and network service provider as:

1. 10G hardware is cheaper compared to other existing hardware.
2. Ethernet Mobile Backhaul and Business Ethernet are still developed since there is demand for higher volume.
3. CWDM Multiplexers are passive and agnostic of speed or protocol.
4. The need for Cloud Networking bandwidth has grown due to greater usage.
5. Devices that are connected using fiber pairs have also increased tremendously.

Moreover, the existing CWDM application has been extended with the addition of two DWDM multiplexers to consist of 30 channels of 10 Gbits/s each that utilizes explicit the CWDM/DWDM.

Multi-channel transmission service TV and transmission service radio are services which transmit the multi-channels of radio or TV to consumers by using the wireless techniques, satellite or wired networking.

1. Multi-channel TV which utilize satellite or other technologies, Mobile, TV.
2. Multi-channel transmission services involve:
3. Cable - TV (CaTV)
4. IP-TV
5. Mobile - TV
6. Multi-channel satellite service.

Providers of multi-channel services need not create content and programs like cable channels or TV. They just do the business of providing multiple channels to their clients using their networks at subscription-based prices or at a specific charge.

12. Conclusion
In summary, this paper argued the use of CWDM to extend the fiber-based timeline. It is possible to increase the lifetime of the install base due to the use of the unexploited fiber array resulting in extra wavelengths being broadcast. Moreover, the protocols used in CWDM are platform-independent that ensures multiple services to be operated through the same fiber. In the manufacturing process of CWDM, wider channel spacing is used as compared to DWDM that helps in the reduction of cost with respect to the optical components. With the multiple functionalities as well as the capabilities such as manufacturing /operational cost, high throughput in terms of transmission and simple design concept. CWDM resulted in better outcomes in comparison with conventional DWDM. Thus, it is considered a better choice with respect to capital expenditure.

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