



- (51) **International Patent Classification:**
H04J 14/02 (2006.01) *H04B 10/25* (2013.01)
- (21) **International Application Number:**
PCT/US2015/018360
- (22) **International Filing Date:**
2 March 2015 (02.03.2015)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
61/947,210 3 March 2014 (03.03.2014) US
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- (81) **Designated States** (*unless otherwise indicated, for every
kind of national protection available*): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY,

BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM,
DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT,
HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR,
KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG,
MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM,
PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC,
SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN,
TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

- (84) **Designated States** (*unless otherwise indicated, for every
kind of regional protection available*): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ,
TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU,
TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE,
DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU,
LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK,
SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ,
GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

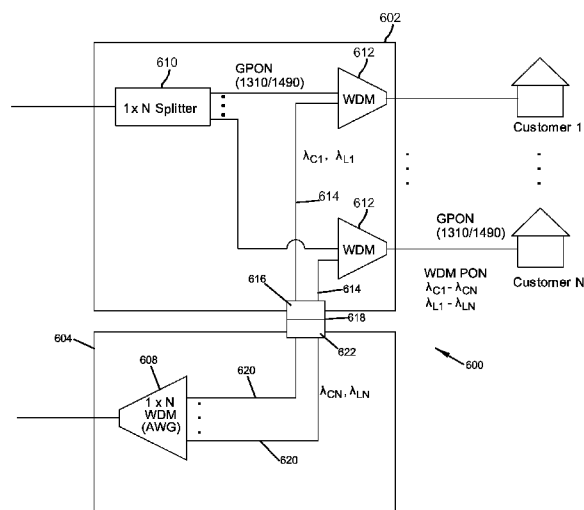
- *as to applicant's entitlement to apply for and be granted a
patent (Rule 4.17(ii))*
- *as to the applicant's entitlement to claim the priority of the
earlier application (Rule 4.17(iii))*

Published:

- *with international search report (Art. 21(3))*

(54) **Title:** PASSIVE OPTICAL NETWORK DISTRIBUTION SYSTEMS AND COMPONENTS THEREOF

FIG. 12



(57) **Abstract:** Systems and methods for delivering multiple passive optical network services are disclosed. One system includes a first optical transmission service comprising a common wavelength pair routed from a source to each of a plurality of subscribers and a second optical transmission service comprising a plurality of unique wavelength pairs, each of the unique wavelength pairs assigned to a subscriber among the plurality of subscribers. The system includes a splitter optically connected to first fiber carrying the first optical transmission service, the splitter including a plurality of outputs each delivering the first optical transmission service, and a wavelength division multiplexer connected to a second fiber, the wavelength division multiplexer separating each of the unique wavelength pairs of the second optical transmission service onto separate optical fibers. The system further includes a plurality of second wavelength division multiplexers optically connected to a different output of the plurality of outputs of the splitter and to a different one of the unique wavelength pairs from the wavelength division multiplexer, thereby combining a unique wavelength pair and a common wavelength pair onto a single fiber to be delivered to a subscriber.



**PASSIVE OPTICAL NETWORK DISTRIBUTION SYSTEMS AND
COMPONENTS THEREOF**

Cross-Reference to Related Applications

This application is being filed on March 2, 2015, as a PCT International
5 Patent application and claims priority to U.S. Patent Application Serial No. 61/947,210
filed on March 3, 2014, the disclosure of which is incorporated herein by reference in its
entirety.

Technical Field

The present application relates generally to distribution of passive optical
10 network services, and in particular to passive optical network distribution systems and
components thereof.

Background

Passive optical networks are becoming prevalent in part because service
providers want to deliver high bandwidth communication capabilities to customers.
15 Passive optical networks are a desirable choice for delivering high speed communication
data because they may not employ active electronic devices, such as amplifiers and
repeaters, between a central office and a subscriber termination. The absence of active
electronic devices may decrease network complexity and cost and may increase network
reliability.

20 Passive optical networks may take one or more signals from incoming
fiber(s) and make it available to a number of output fibers. For example, a distribution
cable may include 24 optical fibers and may run from a central office to a distribution
location, such as an equipment enclosure. At the equipment enclosure, each fiber in the
distribution cable may be split into a number of outgoing fibers which are made available
25 to subscribers. For example, passive optical networks may employ 1:2, 1:4, 1:8, 1:16 and
1:32 splitting ratios for each fiber, for making optical data available to subscriber
locations.

In a traditional gigabit passive optical network, a single transmit
wavelength and a single receive wavelength are used in each 1:32 split, requiring 32
30 subscribers to share bandwidth on a single fiber. However, in other systems, such as
WDM systems, dedicated wavelengths are used for each subscriber. Conversion between

gigabit and WDM systems requires substantial reconfiguration of the optical network to take advantage of the dedicated wavelength system. In certain instances, replacing wires leading to subscriber locations would be required. Such re-cabling is costly and time-consuming.

5 For these and other reasons, improvements are desirable.

Summary

In accordance with the following disclosure, the above and other issues are addressed by the following:

10 In a first aspect, a system for delivering multiple passive optical network services is disclosed. One system includes a first optical transmission service comprising a common wavelength pair routed from a source to each of a plurality of subscribers and a second optical transmission service comprising a plurality of unique wavelength pairs, each of the unique wavelength pairs assigned to a subscriber among the plurality of subscribers. The system includes a splitter optically connected to first fiber carrying the
15 first optical transmission service, the splitter including a plurality of outputs each delivering the first optical transmission service, and a wavelength division multiplexer connected to a second fiber, the wavelength division multiplexer separating each of the unique wavelength pairs of the second optical transmission service onto separate optical fibers. The system further includes a plurality of second wavelength division multiplexers
20 optically connected to a different output of the plurality of outputs of the splitter and to a different one of the unique wavelength pairs from the wavelength division multiplexer, thereby combining a unique wavelength pair and a common wavelength pair onto a single fiber to be delivered to a subscriber. The system further includes a band-pass filter receiving the single fiber including the unique wavelength pair and the common
25 wavelength pair, the band-pass filter delivering one of the unique wavelength pair and the common wavelength pair to the subscriber.

In a second aspect, a system for delivering multiple passive optical network services includes a first optical transmission service and a second optical transmission service received on a common fiber, the first optical transmission service comprising a
30 common wavelength pair routed from a source to each of a plurality of subscribers and the second optical transmission service comprising a plurality of unique wavelength pairs, each of the unique wavelength pairs assigned to a subscriber among the plurality of subscribers. The system further includes a splitter positioned at a terminal optically

connected between a central office and a subscriber, the splitter configured to receive the single fiber and output a plurality of optical connections passing the common wavelength pair and each of the plurality of unique wavelength pairs to each of a plurality of subscribers. The system also includes a filter at each of a plurality of subscribers, the filter
5 selected to deliver either the common wavelength pair or one of the plurality of unique wavelength pairs to the subscriber associated with the filter.

In a third aspect, an optical termination enclosure is located between a signal distribution source and a plurality of subscribers. The optical termination enclosure includes a splitter optically connected to a first fiber carrying a first optical transmission
10 service comprising a common wavelength pair to be routed from the source to each of the plurality of subscribers, the splitter including a plurality of outputs each configured to deliver the first optical transmission service through hardened multi-fiber optical connectors of the optical termination enclosure. The enclosure further includes a wavelength division multiplexer connected to a second fiber carrying a second optical
15 transmission service comprising a plurality of unique wavelength pairs, each of the unique wavelength pairs to be assigned to a subscriber among the plurality of subscribers, wherein the wavelength division multiplexer is configured to separate each of the unique wavelength pairs of the second optical transmission service onto separate optical fibers which are output from the optical termination enclosure through hardened multi-fiber
20 optical connectors.

Brief Description of the Drawings

Figure 1 is a schematic view of a system for delivery of multiple passive optical network services, according to one embodiment of the present disclosure;

25 Figure 2 shows a schematic view of a system for configurable delivery of passive optical network services, according to one embodiment of the present disclosure;

Figure 3 shows a schematic view of a system for configurable delivery of passive optical network services, according to a second embodiment of the present disclosure;

30 Figures 4A-4B show schematic views of subscriber equipment useable with the systems of Figures 2-3, according to one example embodiment of the present disclosure;

Figures 5A-5B show schematic views of subscriber equipment useable with the systems of Figures 2-3, according to one example embodiment of the present disclosure;

Figure 6 shows a schematic view of a system for configurable delivery of selectable passive optical network services, according to a further embodiment of the present disclosure;

Figure 7 shows a schematic view of a system for configurable delivery of selectable passive optical network services, according to a further embodiment of the present disclosure;

Figure 8 shows a schematic view of a system for configurable delivery of selectable passive optical network services, according to a further embodiment of the present disclosure;

Figure 9 shows a schematic view of a system for configurable delivery of GPON-based passive optical network services, according to a further embodiment of the present disclosure;

Figure 10 shows a schematic view of a system for configurable delivery of WDM-based passive optical network services, according to a further embodiment of the present disclosure;

Figures 11A-11C schematically illustrate a variety of different fiber deployment configurations for delivering WDM-based passive optical network services according to the present disclosure; and

Figure 12 schematically illustrates an example method and system for providing deferred delivery of WDM-based passive optical network services according to the present disclosure.

Detailed Description

Various embodiments of the present invention will be described in detail with reference to the drawings, wherein like reference numerals represent like parts and assemblies throughout the several views. Reference to various embodiments does not limit the scope of the invention, which is limited only by the scope of the claims attached hereto. Additionally, any examples set forth in this specification are not intended to be limiting and merely set forth some of the many possible embodiments for the claimed invention.

In general, the present disclosure relates to delivery of one or more selectable passive optical network services to a single endpoint, such as a household, a business, or other entity requiring a telecommunications connection to a distribution hub. The present disclosure describes a variety of passive optical network configurations which allow for selective use of one or more of the passive optical network services, thereby allowing selective upgrading of endpoints based on customer desires or requirements. The methods and systems of the present disclosure allow use of the same optical fibers already deployed to customer homes.

The present disclosure is designed to enable providers of data/video/voice services who have currently deployed fiber-to-the-premise (FTTP) distribution networks for those services, be able to upgrade customers to higher data rate & bandwidth service(s) while maintaining the other services in their current delivery format. For example, a service provider may upgrade its data service to deliver individual customers with a dedicated 1 Gbps or 10 Gbps data line via a DWDM passive optical network (DWDM PON) while continuing to deliver voice and video to that same customer on its traditional gigabit PON (GPON). However, both would be delivered to the customer premise on the same already installed fiber. In this example, the service provider would not have to upgrade all of its delivery equipment to work with the new DWDM PON system but can use the fiber network that is already deployed in the field to deliver all of these services. Additionally, the present disclosure allows for switchover of individual customers from a GPON network to a WDM-based PON network, thereby providing a dedicated service (e.g., 1 Gbps or 10 Gbps service) to that customer rather than requiring the customer to connect via a time-shared optical network with other subscribers, thereby reducing the effective bandwidth available to that subscriber.

Referring now to Figure 1, a generalized network in which aspects of the methods and systems of the present disclosure may be implemented. The network 10 as shown is a passive optical network (PON) such as can contain various fiber-to-the-premise (FTTP) systems. The network 10 connects a source 102, such as a central office of a telecommunications provider, to various subscribers 104, allowing the subscribers high speed data communications to other subscribers within the network and outside of the network (through other communication channels of the source). The network 10 includes a number of fiber optic components 103 that allow the network to route specific fiber optic signals to a subset of the entire subscriber base, thereby allowing the central office 102 to manage bandwidth concerns. The components can include, for example, splices, splitters,

wavelength division multiplexers, repeaters, filters, and other optical components. These components may be modularly added or removed from the fiber optic system, such as by placing various combinations of such equipment in a fiber distribution hub or other modularly extensible system. The systems of the present disclosure breakout multifiber
5 cable down to single fiber, limited wavelength spectra to allow a small number of users to share a particular available bandwidth. For example, in the case of gigabit PON, 32 subscribers 104 typically share a single wavelength for transmitting and receiving data with the source 102. In the case of a WDM-based PON, each subscriber has a dedicated wavelength pair which it uses to communicate with the source 102, thereby effectively
10 increasing the bandwidth to that subscriber as compared to gigabit PON by eliminating competing traffic using that subscriber's communication wavelength.

Referring now to Figures 2-10, various systems for delivery of multiple passive optical network services are shown. These systems can be located within the network 10 of Figure 1, and provide at least a portion of the connecting optical
15 components used to connect a source 102 to subscribers 104.

Referring now to Figure 2, a schematic view of a system 100 for delivery of multiple passive optical network services is shown, according to one embodiment of the present disclosure. The system 100 connects optical fibers from a source 102, shown as a central office or OLT, to one or more subscribers 104, shown as customers or ONT
20 connections. The system receives an initial distribution fiber 106 leading from the source 102, on which all spectra of optical transmission coexist. That initial distribution fiber 106 can include, for example, both GPON services (e.g., operating on 1310 nm uplink and 1490 downlink optical frequencies) as well as a spectrum useable for WDM-based PON distribution. At the system 100, which can be implemented at a terminal or other location
25 between a central office 102 and subscribers 104a-n, the fiber 106 is received at a wavelength division multiplexer 108, which separates the GPON service wavelengths from the WDM-based PON wavelengths. The GPON wavelengths are routed to a splitter 110, which power-splits the GPON signal up to 32 or more ways (one per subscriber). The WDM-based PON wavelengths are routed to a cyclic arrayed waveguide grating
30 (AWG) 112 that operates as a WDM to split uplink and downlink wavelengths (λ_C , λ_L , respectively) onto separate fibers. Those separate fibers can then be routed to a 2:1 WDM 114 which combines one WDM wavelength pair with one output from the splitter 110, to

provide an output of the system 100 a combined GPON and WDM-PON signal. That signal can then be selectively connected to a subscriber 104, as shown.

Generally, in the configuration shown in Figure 2, a single fiber is disposed between the central office 102 and the system 100 (e.g., the terminal). This fiber will
5 carry combined GPON and C-band/L-band WDM-PON services, with 32 C-Band and 32 L-Band wavelengths used. The terminal will, in this embodiment, include 35 or more optical components, with WDM 108, splitter 110, AWG 112, and 32 separate 2:1 WDMs 114. This allows for delivery of a single fiber to a subscriber 104, with no need to change any connections at the terminal when transferring between GPON and WDM-PON
10 services; only a change to an end unit is contemplated, as illustrated in Figures 4A-4B and 5A-5B, described below.

Additionally, it is noted that the loss levels at the system 100 will typically be expected to be about 7-8 dB on the WDM-PON signals, due to passage through WDMs 108, 114, as well as AWG 112. By way of contrast, loss on the GPON signals may be on
15 the level of 18-20 dB, due to the power split component of splitter 110.

Referring now to Figure 3, an alternative configuration for a system 150 is shown. System 150 generally corresponds to system 100 of Figure 2, but rather than using a single fiber 106 between the central office, separate fibers 106a-b are used for the GPON and WDM-PON services, respectively. This eliminates the WDM 108 at the system 150,
20 thereby simplifying and cost-reducing that terminal implementation, and reducing the loss involved (while trading off the requirement of an additional fiber between the central office 102 and the system 150).

Referring to Figures 4A-4B, an example implementation of equipment used at a subscriber 104 is shown, and which allows for transitioning between GPON and
25 WDM-PON services. Figures 4A-4B illustrate an arrangement in which a subscriber receives an input fiber connection which may include signals at both GPON and WDM-PON wavelengths. When the subscriber is registered for GPON services, that subscriber may utilize the configuration in Figure 4A in which a filter 160 receives signals and filters the WDM-PON signals, passing GPON signals to a home unit. Similarly, the system can
30 include a transmitter/receiver 170 that is configured to transmit and receive at GPON wavelengths (e.g., 1310/1490 nm).

When converting to WDM-PON, a subscriber will generally substitute that equipment for new equipment that includes a filter 165 tailored to the wavelengths selected for that subscriber, and a transmitter/receiver 175 that also falls within that band.

In some embodiments, the selected wavelengths are close together (e.g., do not have intervening used wavelengths) such that a band-pass filter allows passage of both uplink and downlink (transmit and receive) wavelengths, while blocking wavelengths dedicated to other subscribers or which are used for GPON.

5 Figures 5A-5B illustrate an alternative configuration for equipment used at a subscriber 104 for transitioning between GPON and WDM-PON services. In this embodiment, rather than using a transmitter and receiver within a particular band passable by filter 160, a transmitter 190 can be configured to transmit either of GPON or WDM-PON services. As such, in some cases a subscriber could be allocated dedicated uplink
10 wavelength and downlink wavelength, or only a dedicated downlink wavelength in alternative embodiments. In particular, as shown in Figure 5A, a receiver 180 and transmitter 190 are configured for use at GPON wavelengths (1310 nm uplink and 1490 nm wavelength downlink). In Figure 5B, a receiver 185 can be tuned to a particular WDM frequency, and a transmitter 195 can either be within a band matched to filter 165
15 (which also encompasses the receiver 185), or can be configured to transmit on some other frequency, for example a return dedicated wavelength for WDM-PON or a GPON wavelength.

 In alternative embodiments beyond those described in connection with Figures 4A-4B and 5A-5B, other arrangements can be used at subscriber premises for
20 selecting from between GPON and WDM-PON services. For example, in some cases, different filters can be used for uplink and downlink wavelengths, and a transmitter from the subscriber may be tunable to a desirable uplink wavelength to avoid the requirement of replacing subscriber systems when switching from GPON to WDM-PON. In still further arrangements, a subscriber may be switched from GPON to WDM-PON for only
25 downlink wavelengths, and may have a shared uplink wavelength on the GPON service if both services are delivered to that subscriber concurrently. Such arrangements could be enabled by different combinations of filters and selected transmission systems at the subscriber used for generating uplink signals having one or more predetermined wavelengths. In a still further example embodiment, a white light transmitter could be
30 paired with a filter either preconfigured to pass L-band (uplink) wavelengths or that is configurable to pass tunable uplink wavelengths back to the terminal (e.g., terminals 100, 150, or those discussed below) to the central office 102.

 Figure 6-7 illustrate further arrangements of a system for configurable delivery of passive optical network services, according to further embodiments of the

present disclosure. In general, Figure 6 illustrates a system 200 in which, rather than using a WDM 114 to route both GPON and WDM-PON signals to a subscriber 104, a 6-port WDM 120 can be used, which can combine GPON signals with multiple wavelengths output from AWG 112. As such, a number of WDMs is reduced, thereby cost-reducing the overall system 200. In particular, rather than using 35 passive components in system 100, system 200 utilizes 19 components.

Figure 7 illustrates an analogous variant of Figure 6 as is shown in Figure 3 relative to Figure 2; that is, in Figure 7, two input fibers 106a-b are used and routed to system 250, which eliminates WDM 108 from that system.

Figure 8 illustrates a further variation of a system 300 for delivering passive optical network services to a subscriber 104. In system 300, a received combined signal on fiber 106 is routed to WDM 108, which separates GPON signals from WDM-PON signals as discussed above. The GPON signals are routed to 1x32 splitter 110, while the WDM-PON signals are routed to a filter array 302, which is illustrated as a plurality of filters 302a-n which each selectively pass a narrow band of wavelengths. As such, the filter array 302 operates as a wavelength division multiplexer that separates (or combines) an inbound wavelength onto separate “channels” that include both C-Band and L-Band wavelengths. Such wavelength bands can be multiplexed with GPON signals at WDM 114 to deliver either GPON, WDM-PON, or combined services to a particular subscriber 104, thereby again avoiding the requirement of service at a particular subscriber to switch over to an “upgraded” WDM-PON service. In alternative embodiments, and analogous to those described above, a further variation of Figure 8 would involve delivering WDM-PON and GPON services on separate fibers to the system 300, thereby removing the WDM 108.

Referring to Figures 9-10, a further possible system 400 is shown, according to an example embodiment. In the example of Figure 9, a system 400, such as an outside plant terminal, can receive combined GPON and WDM-PON services on an input fiber 106, and split that signal using splitter 402, which can be, in some embodiments, a 1x32 power splitter. Each output signal of that splitter, which retains the GPON and all WDM-PON wavelengths, would then be delivered to a subscriber. In the arrangement of Figure 9, a GPON subscriber would include GPON equipment, including a GPON filter 460, at the subscriber premises, thereby filtering out all WDM-PON wavelengths (shown as C-band wavelengths λ_{C1} - λ_{CN} , and L-band wavelengths λ_{L1} - λ_{LN}).

The subscriber would then also be configured to deliver GPON return signals, such as may be accomplished using any of the subscriber configurations illustrated in Figures 4A or 5A.

By way of contrast to Figure 9, in Figure 10, a WDM band-pass filter 465
5 can be installed at the subscriber 104, such that the GPON and other non-selected WDM-PON wavelengths are filtered, and a particular set of C-band and L-band wavelengths (shown as λ_{C1} , λ_{L1}) are allowed to pass through for use by the subscriber 104.

In comparison to the arrangements of Figures 2-3 and 6-8, the arrangement of Figures 9-10 delivers all WDM-PON wavelengths to each subscriber, and therefore the
10 filter 465 at each WDM-PON subscriber must be uniquely useable by that subscriber (e.g., physically keyed or otherwise uniquely identifiable) such that no two subscribers utilize the same downlink or uplink wavelengths to avoid collision of data from those subscribers (e.g., because in the WDM-PON case, no time division multiplexing is provided because it is presumed that the service is dedicated to a specific subscriber). Additionally, although
15 the design at the system 400 of the terminal is simplified, other arrangements may be selected for other reasons. For example, the arrangement of Figures 9-10 may be disadvantaged for WDM-PON subscribers, since each of the WDM-PON signals is power-split at splitter 402. In the other arrangements discussed herein, WDM-PON signals are not power-split in this manner.

20 In each of the above cases, although some reconfiguration of equipment at a subscriber may be required, in the variety of example embodiments provided herein, little or no reconfiguration of connections at a terminal between a central office 102 and a subscriber 104 is required, thereby simplifying maintenance and/or configuration services that would otherwise be performed by a service provider. Furthermore, installation of new
25 equipment at a subscriber could be performed either by providing a self-install kit to a subscriber or by installing an automatically or remotely configurable filter and/or transmission system that utilizes a tunable optical transmitter at the subscriber to vary the L-band (uplink) frequency that is used.

Overall, in each of the above-described situations, GPON subscribers can
30 each utilize common equipment at the subscriber premises, since those subscribers will utilize the same uplink and downlink frequencies. However, as subscribers migrate to WDM-PON systems, those subscribers will receive dedicated wavelengths and will utilize a preconfigured or tunable system at assigned L-band and C-band (uplink and downlink)

wavelengths. Such subscribers can be managed using a wavelength assignment or tracking system that validates that user's dedicated WDM-PON wavelength, for example using a tracking application.

In various examples of the present disclosure, delivery of gigabit passive optical networks and WDM passive optical networks are considered; however, deployment of additional types of optical networks is possible as well using the systems and techniques disclosed herein. For example the present disclosure also relates to delivery of other types of systems with different wavelengths and parallelism, such as various WDM-PON arrangements. Furthermore, other embodiments are possible as well which include different levels and combinations of splitters, filters, and wavelength division multiplexers. Examples of other variations are described in U.S. Patent No. 8,559,818, the disclosure of which is hereby incorporated by reference in its entirety.

In the embodiments disclosed herein, the systems for delivery of multiple passive optical network services are illustrated as passive optical modules. However, it is understood that the system can be configured from a number of separate components, and could include additional passive or active optical components. Furthermore, additional optical networking components can be incorporated into networks having the systems described herein.

Additionally, it is noted that the uplink and downlink wavelengths can be configured in various ways. For example, in some embodiments (e.g., as discussed in connection with at least Figures 8-10, C-band and L-band wavelengths are adjacent one another, meaning that no other C-band or L-band wavelength assigned to a different subscriber of the subscribers connected to the terminal are provided between those wavelengths. In alternative arrangements in which an AWG is configured to route individual wavelengths or wavelength bands to a particular output, various wavelength combinations may be used, which may or may not be adjacent. This is also the case if, on uplink, the GPON services are used, with a non-dedicated uplink channel.

Through use of the systems disclosed herein, a provider of passive optical network services can connect multiple services to a single subscriber location while avoiding laying additional fibers to those locations. A provider or maintainer of an optical network such as are disclosed herein can install the splitters, filters, and wavelength division multiplexers as described herein to split a common wavelength pair into a number of fibers, and to separate unique wavelength pairs onto a corresponding number of fibers. The fibers carrying the common wavelength pair can be joined to each one of the fibers

carrying different unique wavelength pairs to allow connection of a subscriber to either one or both services by using a single preexisting optical fiber connected to the subscriber.

Referring now to Figures 11A-11C, a variety of fiber deployment configurations for delivering WDM-based passive optical network services according to the present disclosure are schematically illustrated. The systems illustrated in
5 Figures 11A-11C allow for convenient switchover of individual customers/subscribers from a GPON network to a WDM-based PON network. Figures 11A-11C relate to configurations or systems where the switchover includes a change of the physical connection at a terminal located between a source such as the central office and a
10 subscriber location. In contrast, the systems described above may include additional components at the terminal locations to allow the subscribers to change between GPON and WDM-PON services without a physical connection change at the terminal.

According to the configuration illustrated in Figure 11A, an outside equipment enclosure, depicted in the form of an optical termination enclosure (OTE) 502,
15 may receive a distribution fiber leading from a source such as a central office including both GPON services (e.g., operating on 1310 nm uplink and 1490 downlink optical frequencies) as well as a spectrum useable for WDM-based PON distribution (or separate fibers for the GPON and WDM-PON services as shown above). According to the example deployment system 500 illustrated in Figure 11A, the depicted OTE 502 includes
20 a splitter 504 (e.g., 1x32) for power splitting the GPON signal. The WDM-based PON wavelengths are routed to a cyclic arrayed waveguide grating (AWG) 506 in the OTE 502 that operates as a WDM to split dedicated pairs of uplink and downlink wavelengths (λ_C , λ_L , respectively) onto separate fibers.

The OTE 502, as depicted, may output GPON and WDM-PON signals
25 through connectors such as hardened multi-fiber optic connectors (HMFOC) 508 leading to further outside equipment enclosures such as multiport service terminals (MST) 510 servicing a number of subscribers. In the depicted embodiment, each MST 510 is shown with eight ports 512 for servicing eight subscribers.

According to the switchover configuration illustrated in Figure 11A, an
30 MST location may receive an upgraded WDM-PON signal by unplugging connectorized cabling from a GPON based output 514 and plugging the connectorized cabling into a WDM-PON based output 516 at the OTE location.

Figure 11B illustrates a variation of the switchover configuration shown in Figure 11A, wherein two MST's 510a, 510b, one dedicated to GPON-based service and one dedicated to WDM-PON service, respectively, are deployed in the field. Subscribers desiring a service upgrade are switched from the GPON dedicated MST 510a to the
5 WDM-PON dedicated MST 510b. In this configuration, if a single subscriber wants to upgrade its service, the entire MST location does not have to be switched over to the WDM-PON based signal and the subscriber can be independently upgraded.

When all of the subscribers/customers of the GPON dedicated MST 510a have switched over the WDM-PON dedicated MST 510b, the now "empty" MST 510a
10 can be used for future service upgrades. For example, the "empty" MST 510a can now be used for a different signal such as a 10Gbps data line if the equipment at the OTE 502 is also upgraded accordingly (e.g., the splitter 504 removed and replaced by other WDM-type equipment that can split the required uplink and downlink wavelengths onto separate fibers). Thus, the already existing, but empty, MST's can now be used to provide
15 convenient signal upgrade switchovers with equipment changes only at the OTE location.

Figure 11C illustrates a variation of the configurations of Figures 11A and 11B, wherein a cable 520 carrying both GPON and WDM-PON based signals are initially deployed, ready for future signal switchovers. The fibers 522 of the cable can be terminated with HMFOC's 508 at both ends. The remote end 524 of the cable 520 can be
20 used for either of the switchover methods described in Figures 11A (one MST switched over) or 11B (dedicated MST's for each of the type of signals).

Figure 12 illustrates a system 600 that is a variation of the systems 100, 150 described above with respect to Figures 2 and 3. The system 600 of Figure 12 illustrates a method for deferred delivery of WDM-based passive optical network services according to
25 the present disclosure.

Even though the system 600 of Figure 12 is configured for connecting optical fibers from a source, such as a central office or OLT, to one or more subscribers, such as customers or ONT connections, the system 600 of Figure 12 is set up to defer the WDM-based PON service until a future desired time for the subscribers.

30 Similar to Figure 3, the system 600 of Figure 12 may receive separate fibers 606a, 606b for the GPON and WDM-PON services, respectively. However, the GPON and the WDM-PON services may be housed in separate housings 602, 604, respectively, and the WDM-PON services may not be fully incorporated into the system 600 until the two separate housings are physically connected. According to one example

embodiment, the housing 604 carrying the AWG 608, which operates as a WDM to split uplink and downlink wavelengths onto separate fibers may be provided a piece of modular equipment that may need to be physically connected to the housing 602 carrying the power splitter.

5 In the specific system 600 shown in Figure 12, the GPON wavelengths are routed to a splitter 610, which power-splits the GPON signal up to n ways (one per subscriber). There are n number of WDM's 612 housed within the same housing 602. As described above with respect to the systems of Figures 2 and 3, the WDM's 612 are configured to combine an output from the power splitter 610 with a WDM wavelength
10 pair. However, the fibers 614 carrying the WDM wavelength pairs are not relayed directly from the AWG 608. The fibers 614 carrying the WDM wavelength pairs are patched to a first connector 616 that has a connection location 618 exposed to an exterior of the housing 602 carrying the power splitter 610 and the WDM's 612. The first connector 616 may be provided as a multi-fiber connector (MPO). Other connectors may also be used.

15 Similarly, fibers 620 carrying the WDM wavelength pairs that have been split by the AWG 608 are also patched to a second connector 622 that is configured to mate with the first connector 616 when the two housings 602, 604 are mated. The second connector 622 may also be an MPO connector. Other connectors that are configured to mate with the first connector can also be used.

20 In this manner, a shared signal being forwarded to a subscriber can be upgraded to a combined GPON and WDM-PON signal by a modular connection provided between the two housings 602, 604 when the upgrade is desired.

 The above specification, examples and data provide a complete description of the manufacture and use of the composition of the invention. Since many embodiments
25 of the invention can be made without departing from the spirit and scope of the invention, the invention resides in the claims hereinafter appended.

Claims:

1. A system for delivering multiple passive optical network services comprising:
 - a first optical transmission service comprising a common wavelength pair routed from a source to each of a plurality of subscribers;
 - 5 a second optical transmission service comprising a plurality of unique wavelength pairs, each of the unique wavelength pairs assigned to a subscriber among the plurality of subscribers;
 - a splitter optically connected to a first fiber carrying the first optical transmission service, the splitter including a plurality of outputs each delivering the first
 - 10 optical transmission service;
 - a wavelength division multiplexer optically connected to a second fiber, the wavelength division multiplexer separating each of the unique wavelength pairs of the second optical transmission service onto separate optical fibers;
 - a plurality of second wavelength division multiplexers optically connected
 - 15 to a different output of the plurality of outputs of the splitter and to a different one of the unique wavelength pairs from the wavelength division multiplexer, thereby combining a unique wavelength pair and a common wavelength pair onto a single fiber to be delivered to a subscriber; and
 - a band-pass filter receiving the single fiber including the unique
 - 20 wavelength pair and the common wavelength pair, the band-pass filter delivering one of the unique wavelength pair and the common wavelength pair to the subscriber.
2. The system of claim 1, wherein the wavelength division multiplexer comprises an arrayed waveguide grating.
- 25 3. The system of claim 1, further comprising a third wavelength division multiplexer optically connected to a fiber received from the central office carrying the common wavelength pair and the plurality of unique wavelength pairs, the third wavelength division multiplexer separating the common wavelength pair from the plurality of unique
- 30 wavelength pairs.
4. The system of claim 1, wherein the splitter comprises a 1:32 splitter.

5. The system of claim 1, wherein the common wavelength pair is received on a first fiber from a central office and wherein the plurality of unique wavelength pairs is received on a second fiber from the central office.
- 5 6. The system of claim 1, wherein the plurality of second wavelength division multiplexers includes one or more six-port wavelength division multiplexers.
7. The system of claim 1, wherein each of the unique wavelength pairs includes an uplink wavelength and a downlink wavelength, wherein the uplink wavelength and the
10 downlink wavelength are adjacent to each other.
8. The system of claim 7, wherein the band-pass filter is located at a subscriber and delivers the unique wavelength pair to the subscriber in the absence of delivering the common wavelength pair.
- 15 9. The system of claim 7, wherein the band-pass filter is located at a subscriber and delivers the common wavelength pair to the subscriber in the absence of delivering the unique wavelength pair.
- 20 10. The system of claim 1, wherein the first optical transmission service is received at a first housing and the second optical transmission service is received at a second housing.
11. The system of claim 10, wherein the first housing includes a connector that connects to the second housing and links the separate optical fibers from the wavelength
25 division multiplexer to each of the plurality of second wavelength division multiplexers.
12. The system of claim 11, wherein the connector comprises a multi-fiber connector.
13. A system for delivering multiple passive optical network services comprising:
a first optical transmission service and a second optical transmission
30 service received on a common fiber, the first optical transmission service comprising a common wavelength pair routed from a source to each of a plurality of subscribers and the second optical transmission service comprising a plurality of unique wavelength pairs,

each of the unique wavelength pairs assigned to a subscriber among the plurality of subscribers;

5 a splitter positioned at a terminal optically connected between a central office and a subscriber, the splitter configured to receive the single fiber and output a plurality of optical connections passing the common wavelength pair and each of the plurality of unique wavelength pairs to each of a plurality of subscribers; and

a filter at each of a plurality of subscribers, the filter selected to deliver either the common wavelength pair or one of the plurality of unique wavelength pairs to the subscriber associated with the filter.

10

14. The system of claim 13, wherein the filter passes a unique wavelength pair including adjacent uplink and downlink wavelengths.

15. An optical termination enclosure located between a signal distribution source and a plurality of subscribers, the optical termination enclosure comprising:

15 a splitter optically connected to a first fiber carrying a first optical transmission service comprising a common wavelength pair to be routed from the source to each of the plurality of subscribers, the splitter including a plurality of outputs each configured to deliver the first optical transmission service through hardened multi-fiber optical connectors of the optical termination enclosure; and

20 a wavelength division multiplexer connected to a second fiber carrying a second optical transmission service comprising a plurality of unique wavelength pairs, each of the unique wavelength pairs to be assigned to a subscriber among the plurality of subscribers, wherein the wavelength division multiplexer is configured to separate each of the unique wavelength pairs of the second optical transmission service onto separate optical fibers which are output from the optical termination enclosure through hardened multi-fiber optical connectors.

25 16. The optical termination enclosure of claim 15, further comprising a first hardened multi-fiber optic connector receiving the first fiber and a second hardened multi-fiber optic connector receiving the second fiber.

FIG. 1

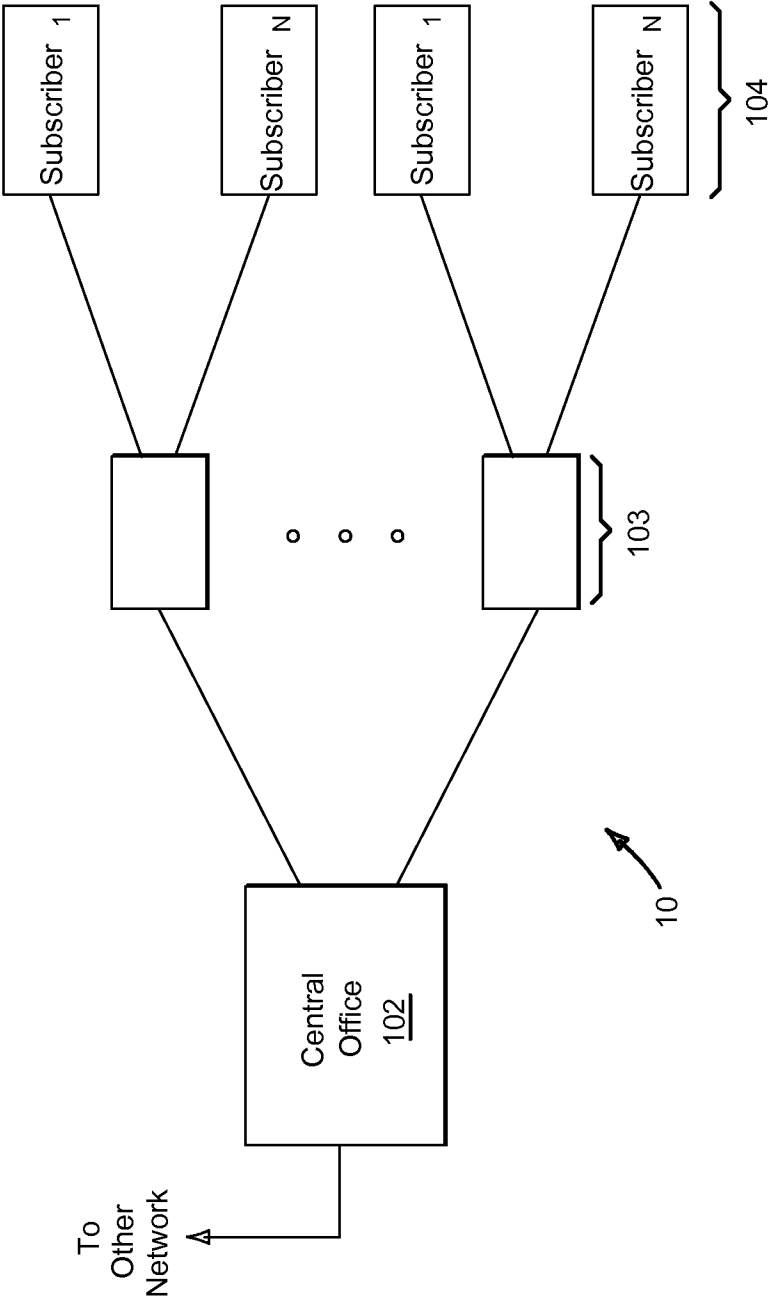


FIG. 2

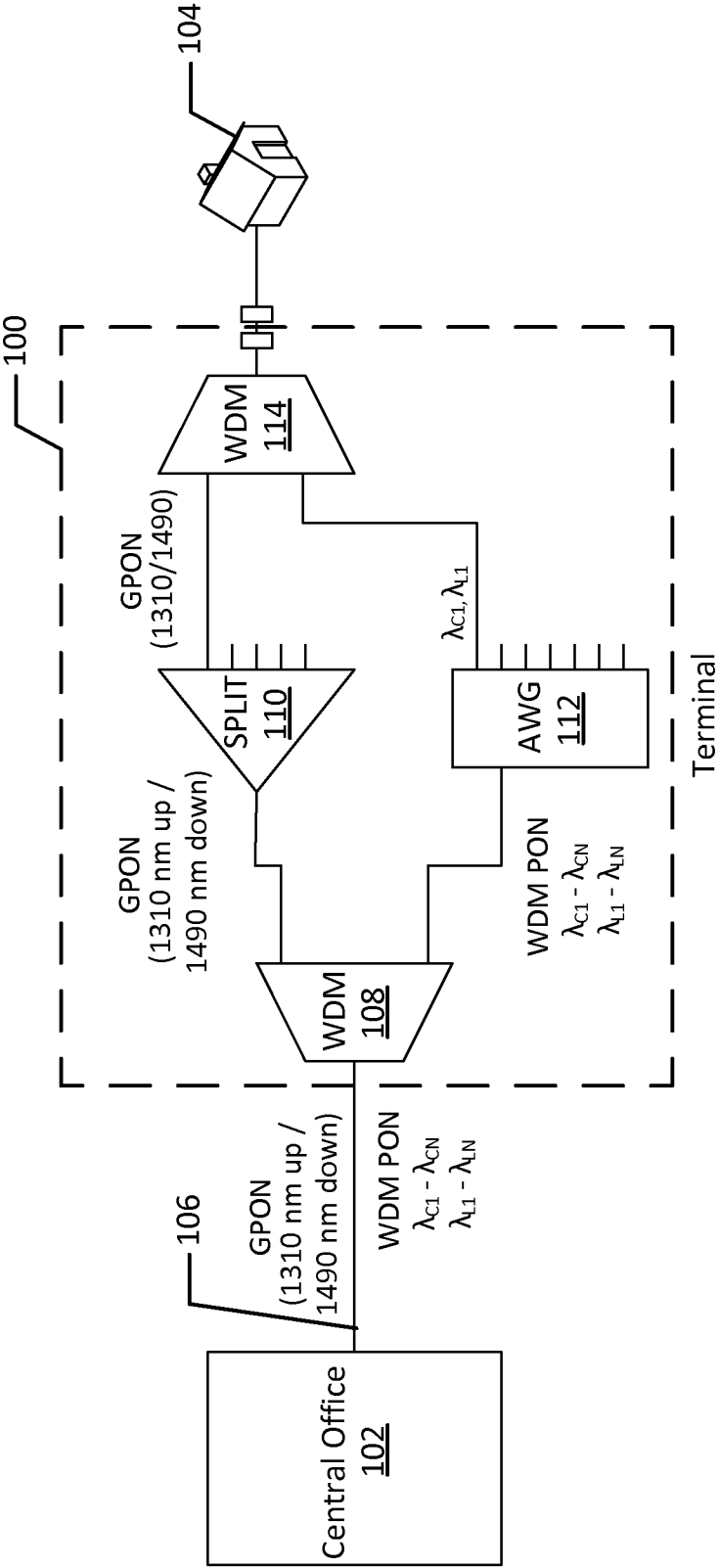


FIG. 3

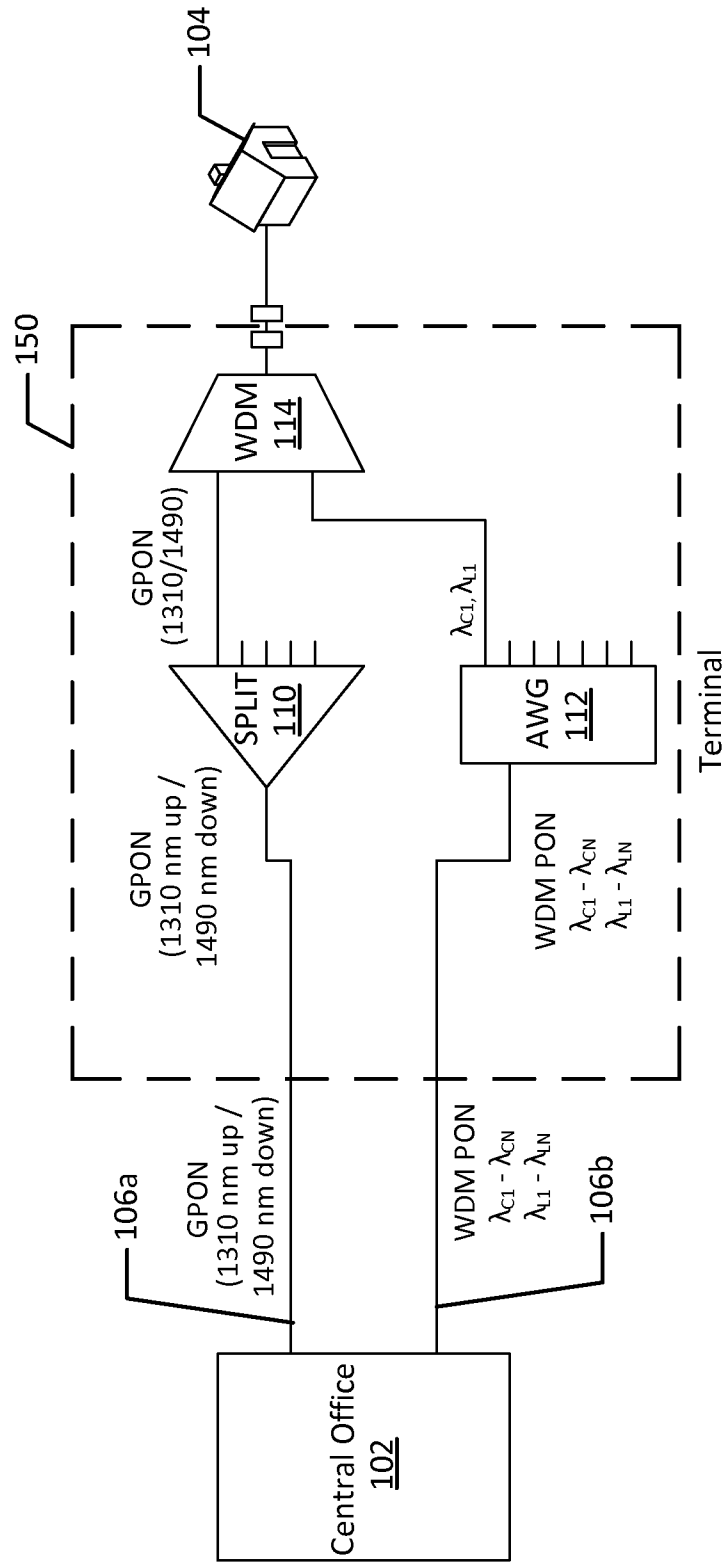


FIG. 4A

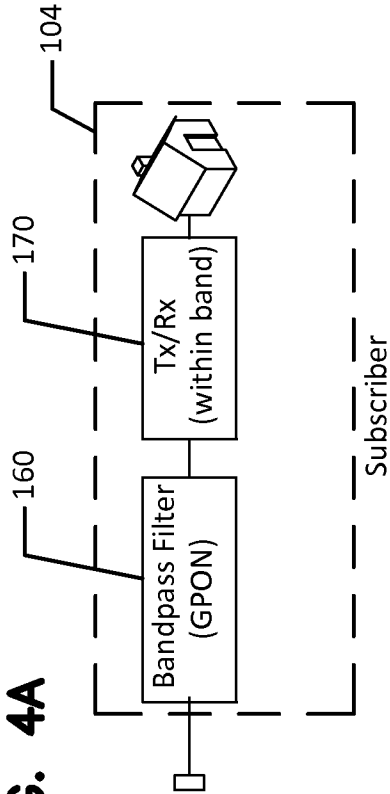


FIG. 4B

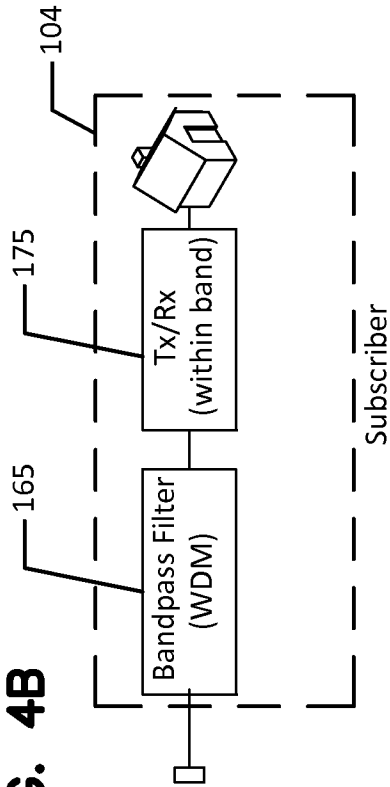


FIG. 5A

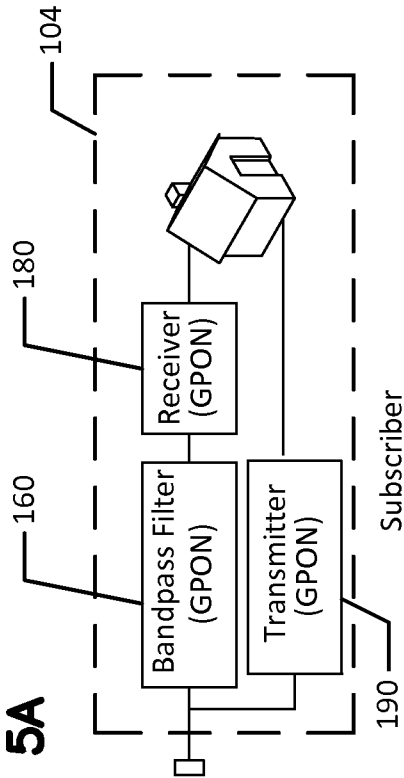


FIG. 5B

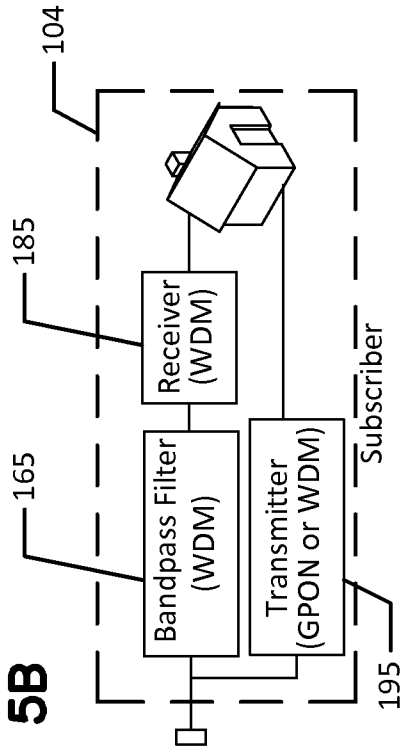


FIG. 6

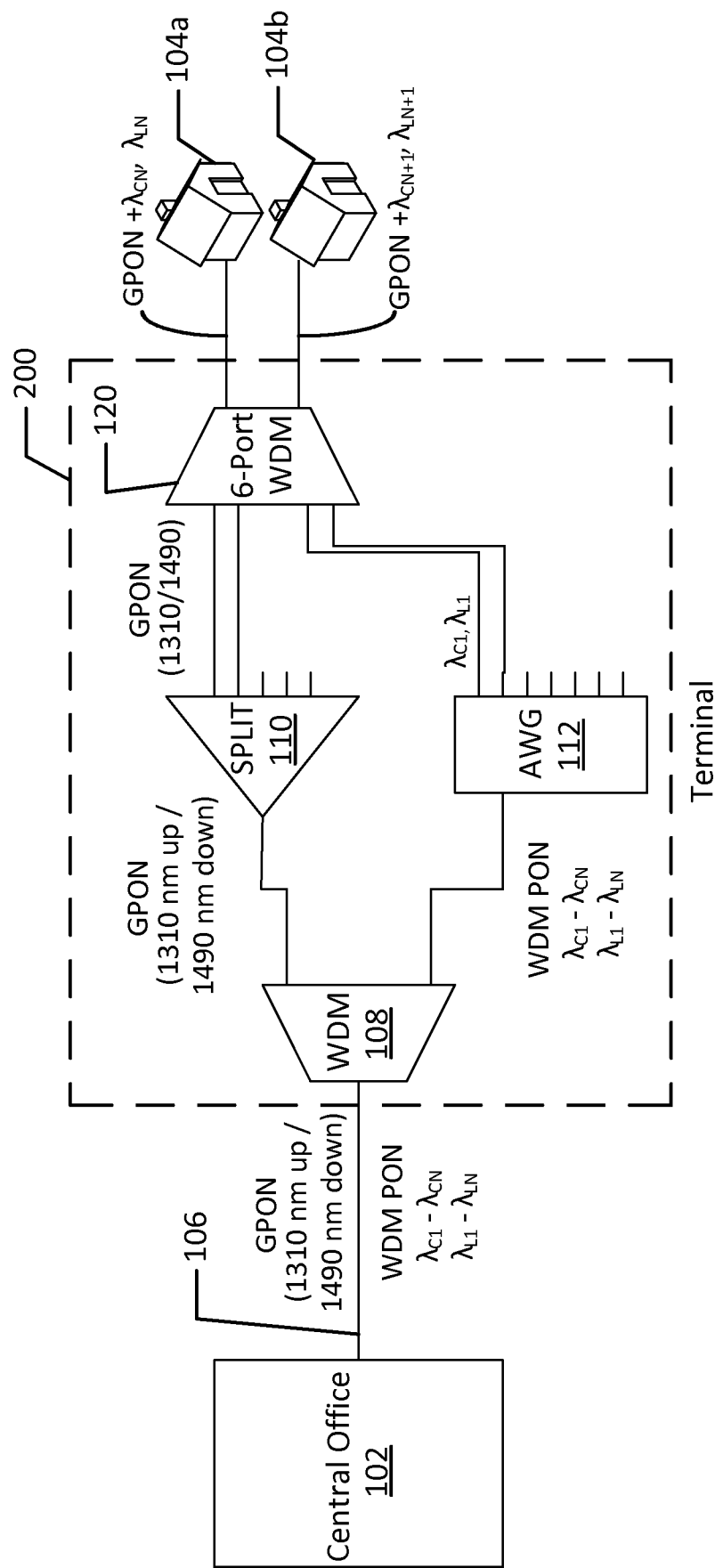


FIG. 7

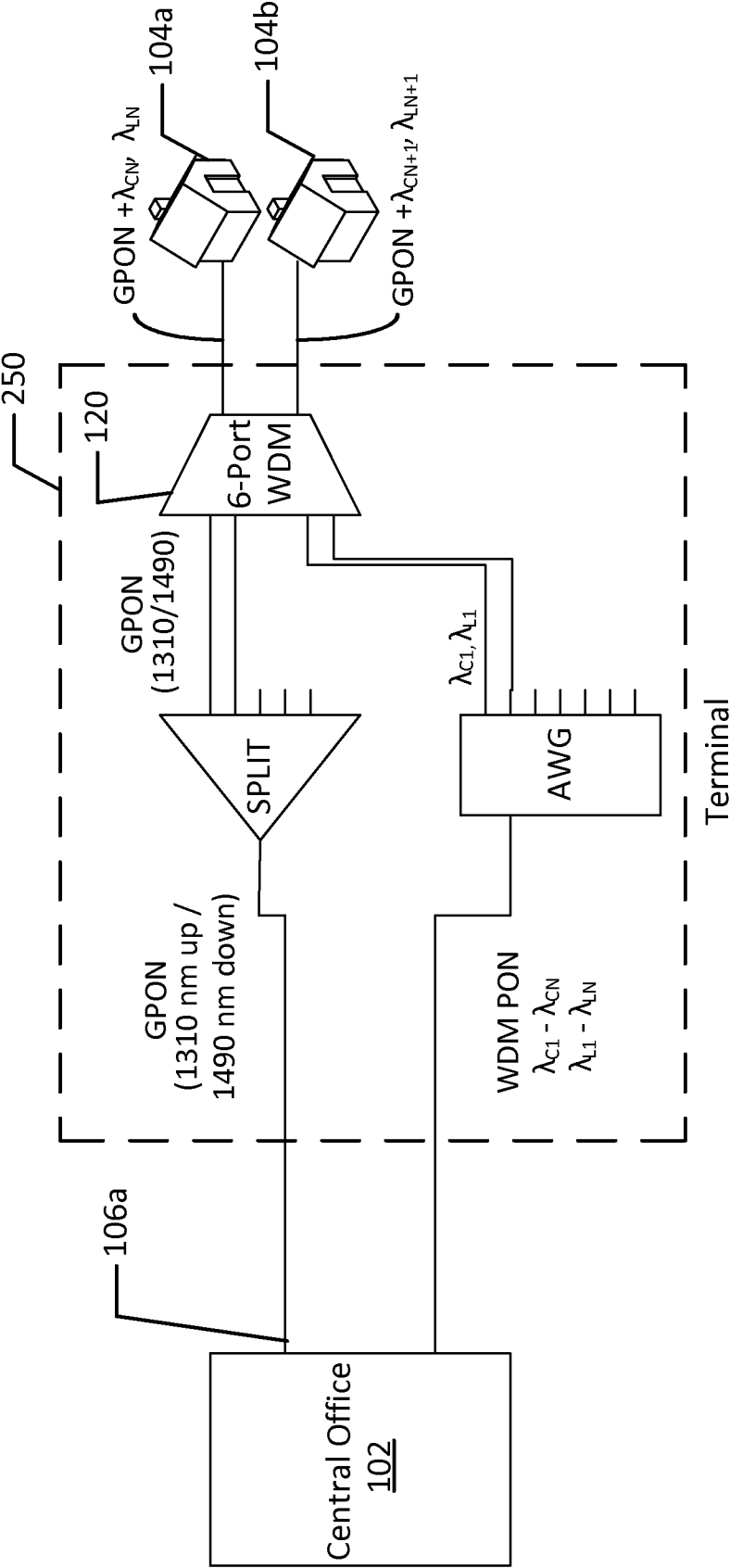


FIG. 8

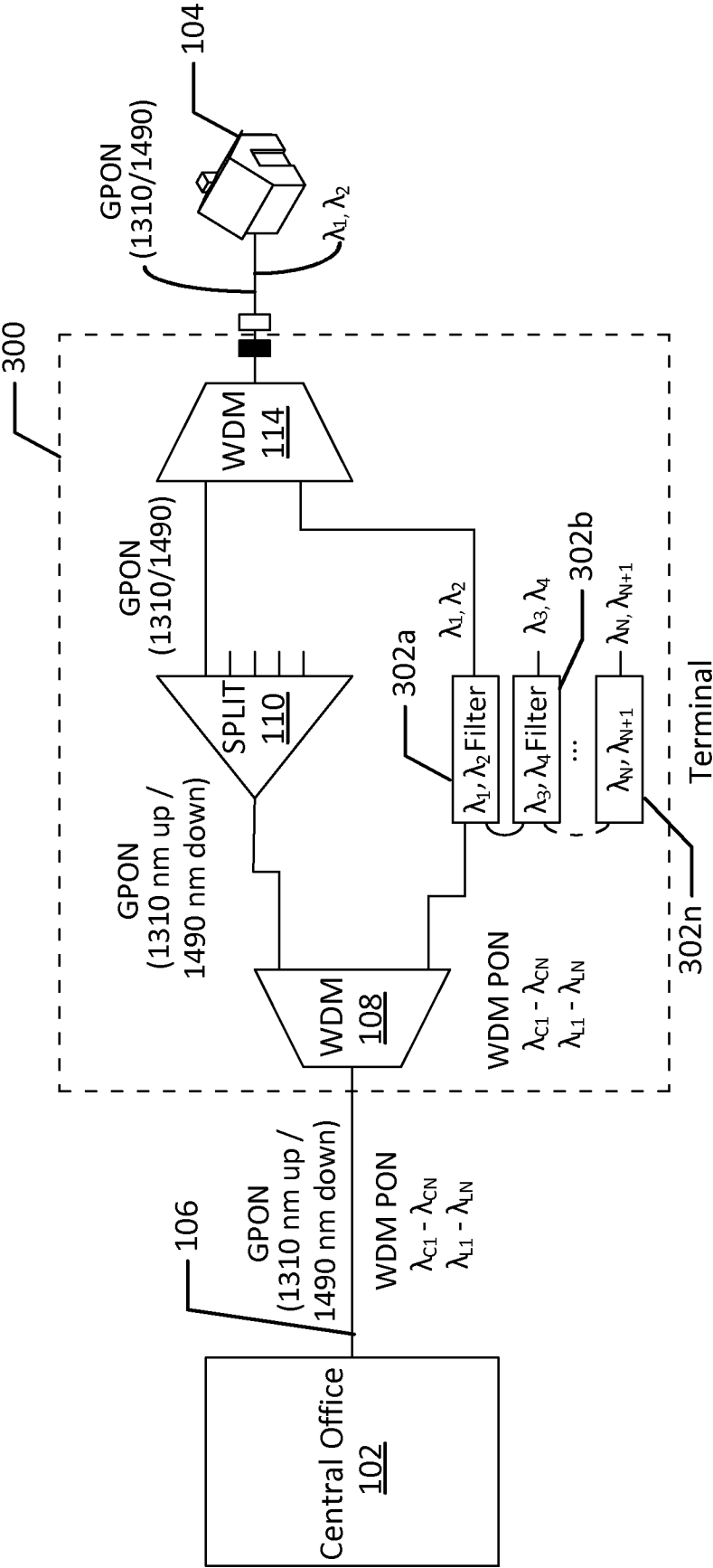


FIG. 9

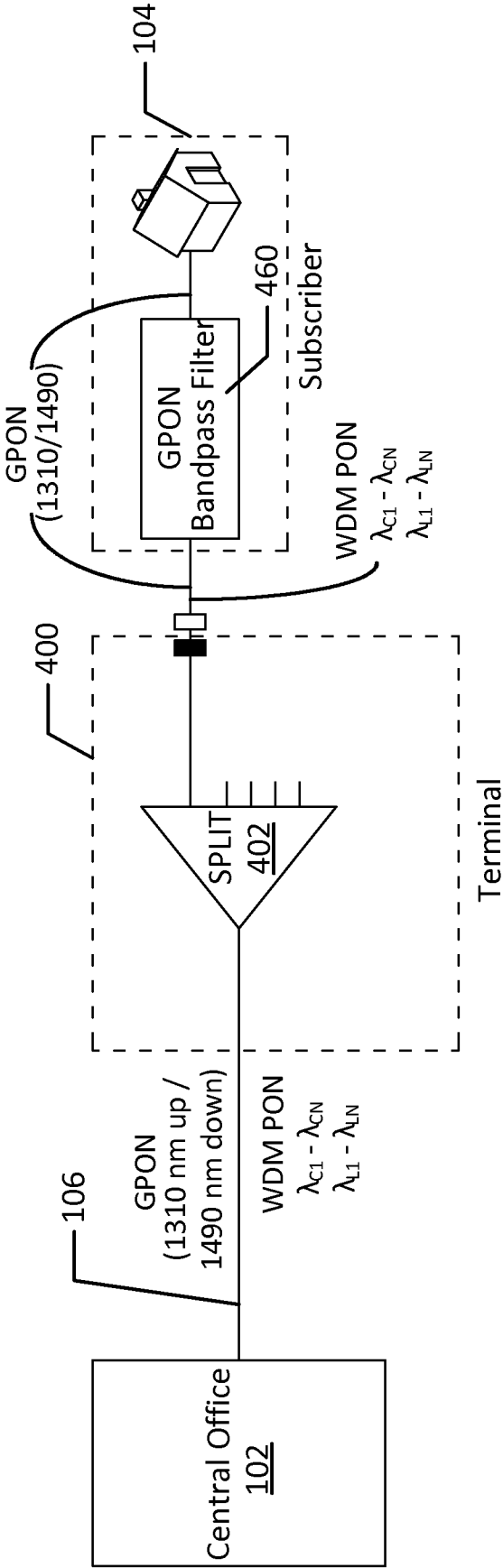


FIG. 10

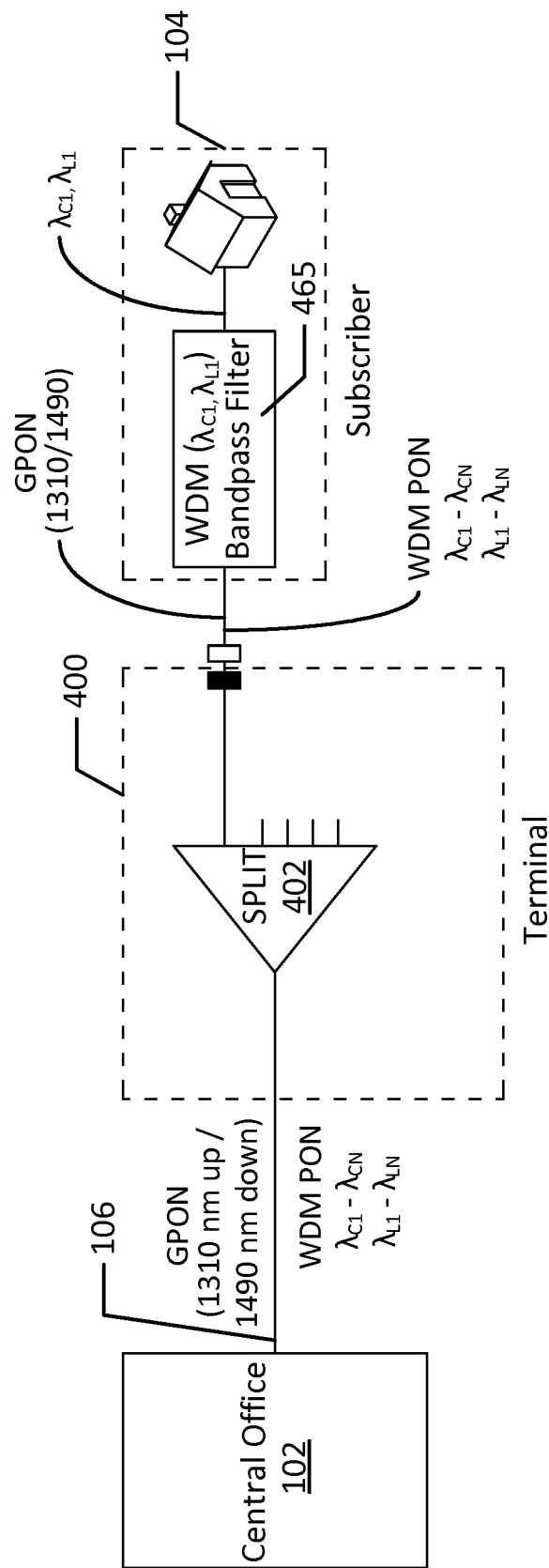


FIG. 11A

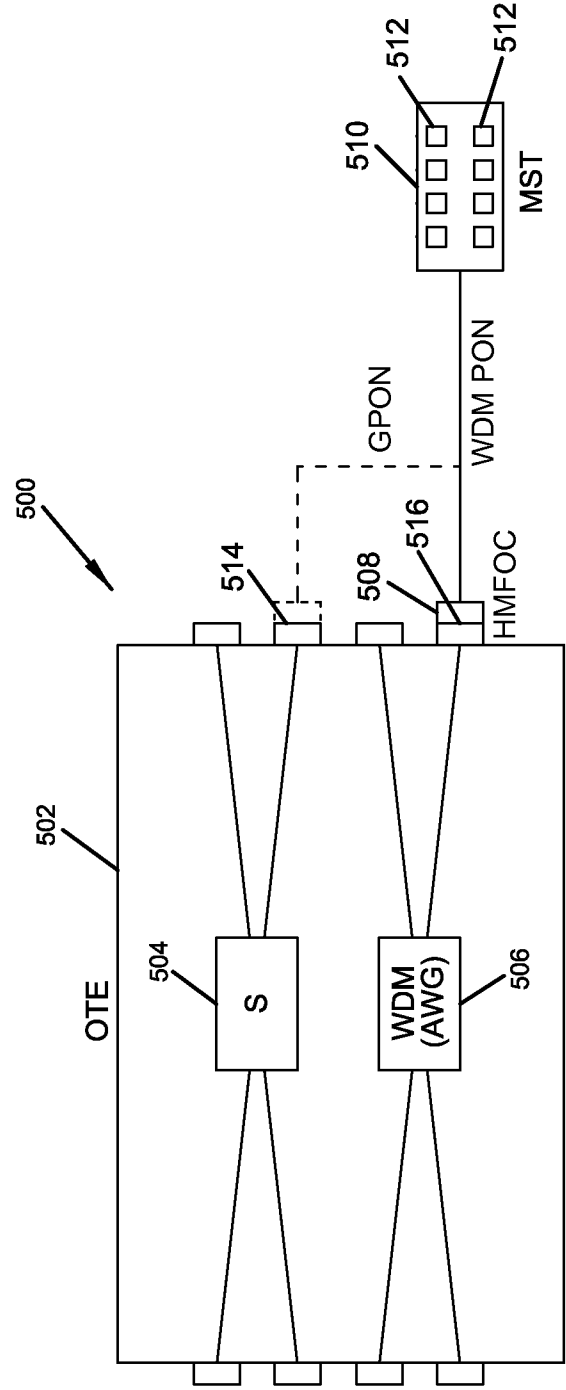


FIG. 11B

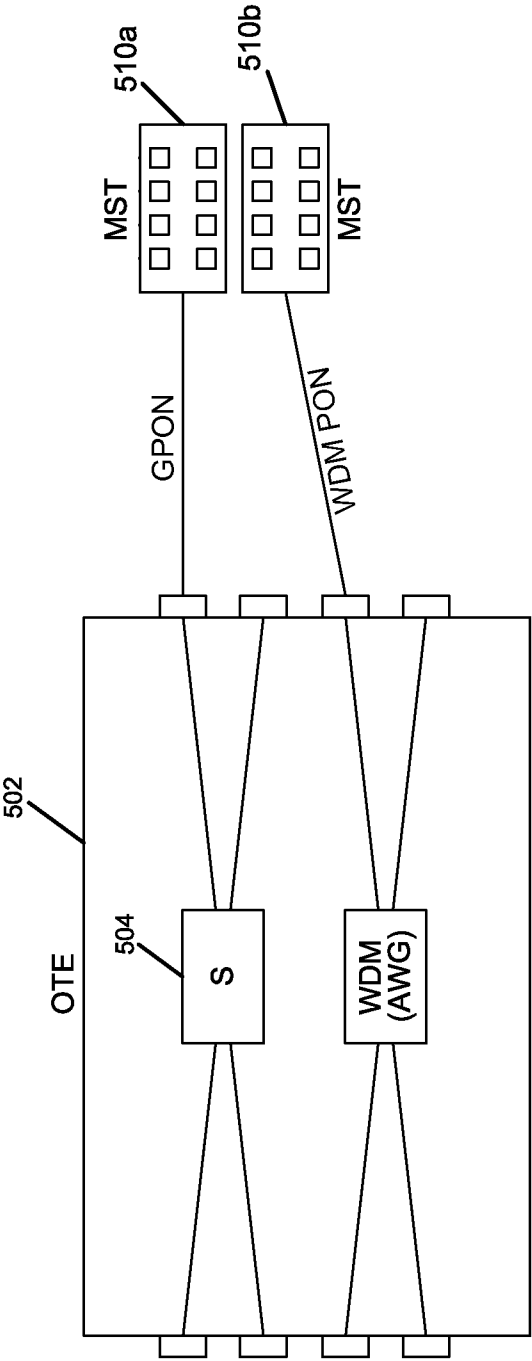


FIG. 11C

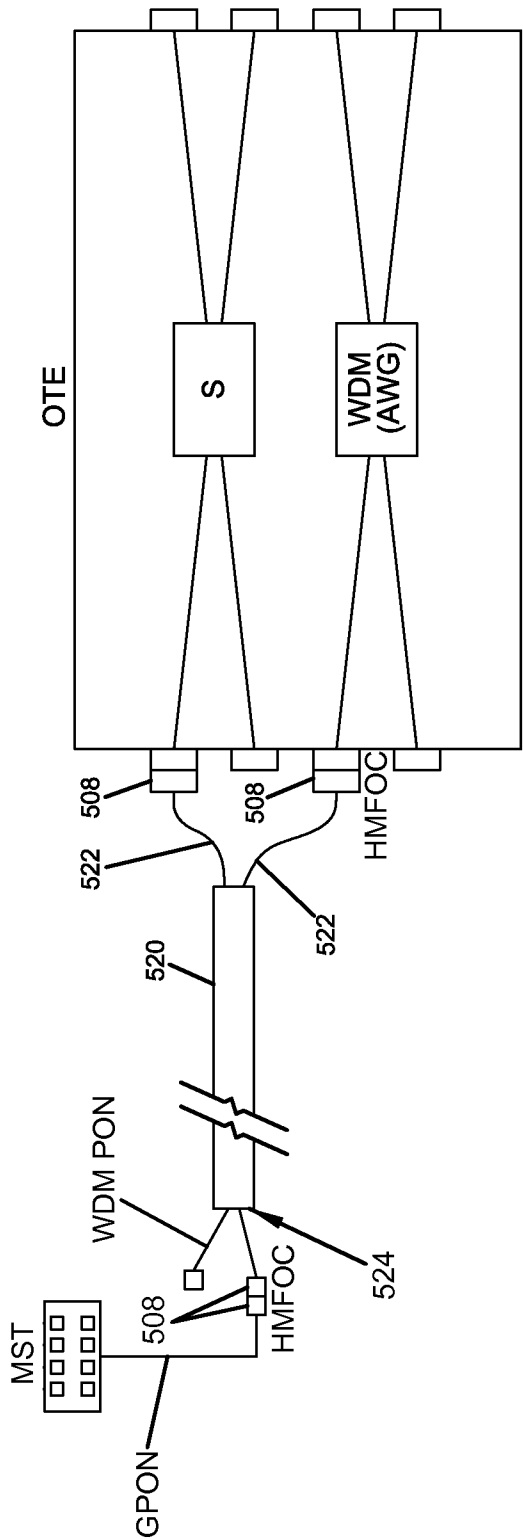
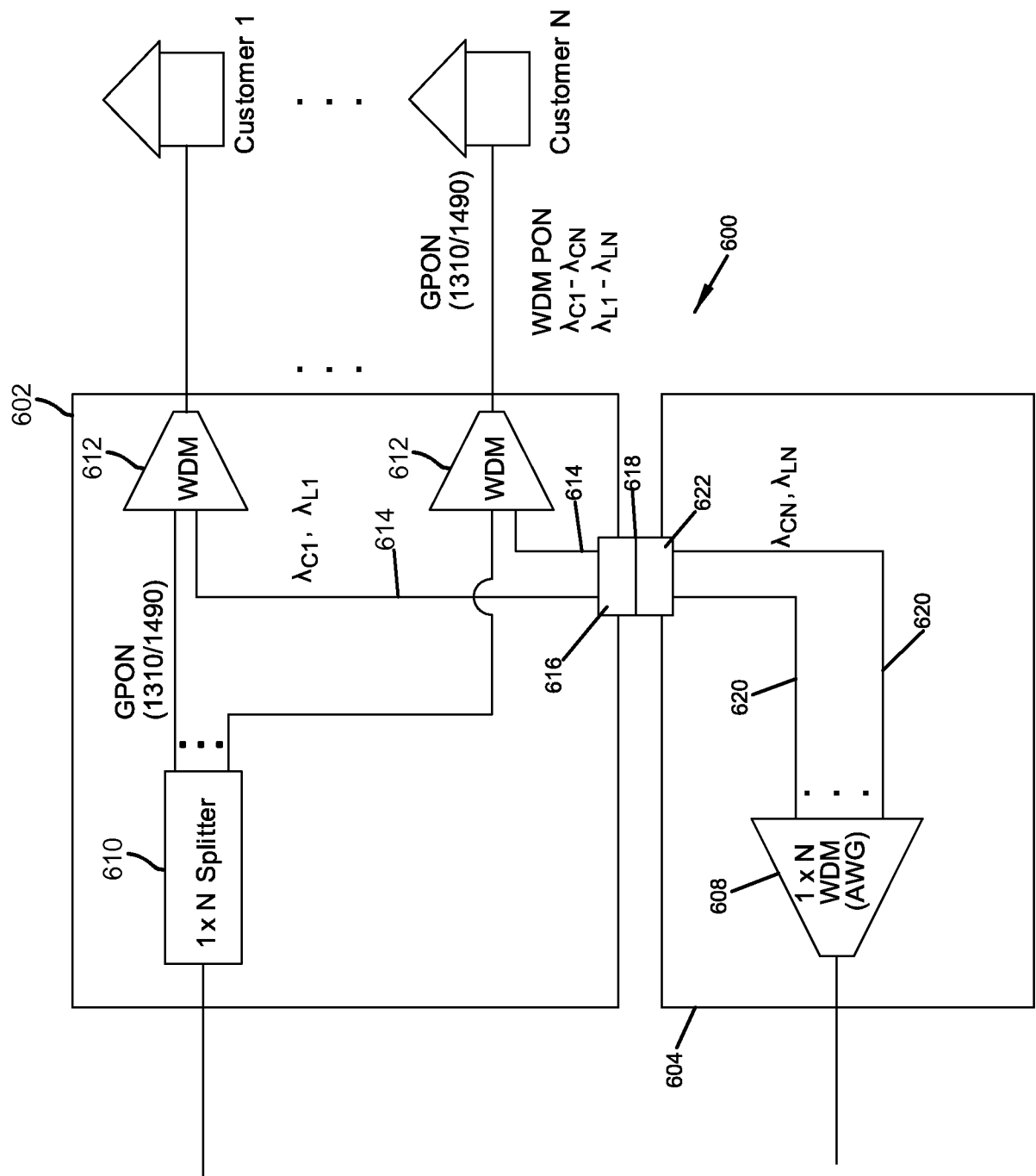


FIG. 12



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/018360**A. CLASSIFICATION OF SUBJECT MATTER****H04J 14/02(2006.01)i, H04B 10/25(2013.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04J 14/02; H04J 14/00; H04J 11/00; H04B 10/25

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & keywords: WDM, PON, splitter, BPF, and similar terms.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2009-0220231 A1 (ADC TELECOMMUNICATIONS, INC.) 03 September 2009 See paragraphs [0004], [0024]-[0026]; claims 1, 2, 5; and figure 2.	15, 16
Y		1-14
Y	US 2013-0183039 A1 (TELEFONAKTIEBOLAGET L M ERISSON (PUBL)) 18 July 2013 See paragraph [0034]; and figure 3.	1-14
A	US 2007-0183779 A1 (MARTIN BOUDA et al.) 09 August 2007 See paragraphs [0010]-[0015]; and figures 3, 4.	1-16
A	US 2007-0230957 A1 (NEC CORPORATION) 04 October 2007 See paragraphs [0009]-[0028]; and figure 21.	1-16
A	KR 10-2013-0084943 A (KOREA ADVANCED INSTITUTE OF SCIENCE AND TECHNOLOGY) 26 July 2013 See paragraphs [0025]-[0030]; and figure 3.	1-16



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

26 May 2015 (26.05.2015)

Date of mailing of the international search report

27 May 2015 (27.05.2015)

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/018360

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2009-0220231 A1	03/09/2009	US 2014-233952 A1 US 8559818 B2 WO 2009-055673 A1	21/08/2014 15/10/2013 30/04/2009
US 2013-0183039 A1	18/07/2013	US 8855492 B2	07/10/2014
US 2007-0183779 A1	09/08/2007	US 07499651 B2 US 07522838 B2 US 07546036 B2 US 07603036 B2 US 07639946 B2 US 07653309 B2 US 07684705 B2 US 07684706 B2 US 07949256 B2 US 08023823 B2 US 08180223 B2 US 08565599 B2 US 2007-0092249 A1 US 2007-0092250 A1 US 2007-0092251 A1 US 2007-0092252 A1 US 2007-0092253 A1 US 2007-0092254 A1 US 2007-0092255 A1 US 2007-0166037 A1 US 2007-0166043 A1 US 2008-0131129 A1 US 2008-0138069 A1 WO 2007-047559 A1 WO 2007-047564 A1 WO 2007-047697 A1 WO 2007-047704 A1 WO 2007-081423 A1 WO 2007-081427 A1 WO 2007-081747 A2 WO 2007-081747 A3 WO 2007-081748 A2 WO 2007-081748 A3 WO 2007-092346 A1 WO 2007-142676 A1 WO 2008-073131 A1	03/03/2009 21/04/2009 09/06/2009 13/10/2009 29/12/2009 26/01/2010 23/03/2010 23/03/2010 24/05/2011 20/09/2011 15/05/2012 22/10/2013 26/04/2007 26/04/2007 26/04/2007 26/04/2007 26/04/2007 26/04/2007 19/07/2007 19/07/2007 05/06/2008 12/06/2008 26/04/2007 26/04/2007 26/04/2007 26/04/2007 19/07/2007 19/07/2007 04/10/2007 19/07/2007 07/09/2007 16/08/2007 13/12/2007 19/06/2008
US 2007-0230957 A1	04/10/2007	DE 602007013132 D1 EP 1841114 A1 EP 1841114 B1 HK 1104704 A1 JP 04747915 B2 JP 2007-274627 A	28/04/2011 03/10/2007 16/03/2011 29/07/2011 17/08/2011 18/10/2007

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/018360Patent document
cited in search reportPublication
datePatent family
member(s)Publication
date

KR 10-2013-0084943 A

26/07/2013

US 07945163 B2

17/05/2011

KR 10-1462434 B1

17/11/2014