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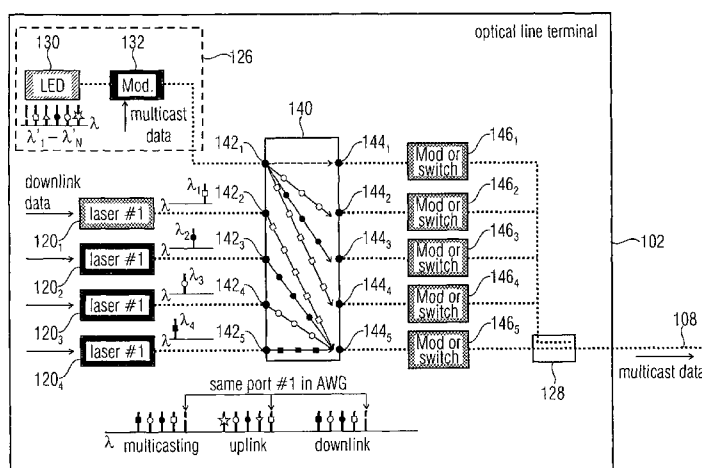


FIG 6

(57) Abstract: A central node (102) for a communication system having a plurality of nodes coupled to the central node (102) by a passive optical network, includes an output port adapted to be coupled to the passive optical network, and a multiplexer/demultiplexer device (140) having a plurality of outputs (144₁-144_N) coupled to the output port, wherein the multiplexer/demultiplexer device (140) is adapted to multiplex optical signals from a plurality of optical sources (120₁-120_N) to one of the plurality of outputs (144₁-144_N), and to demultiplex an optical signal from a broad spectrum optical source (130) to the plurality of outputs (144₁-144_N), and wherein for transmitting data to a group of nodes of the communication system, the central node (102) is adapted to selectively provide the data at the output port using the optical signals at the plurality of outputs (144₁-144_N) of the multiplexer/demultiplexer device (140).

COMMUNICATION SYSTEM AND METHOD FOR TRANSMITTING DATA TO ONE OR MORE GROUPS OF
NODES IN A COMMUNICATION SYSTEM

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Description

Embodiments of the invention relate to wireless communication systems, more specifically to a central node for a communication system having a plurality of nodes coupled thereto by a passive optical network, a wireless communication system, an optical multiplexer/demultiplexer device for a central node of a communication system, and a method for transmitting data to one or more groups of nodes in a communication system. More specifically, embodiments refer to the field of passive optical networks (PON), for example wavelength division multiplexing passive optical networks (WDM-PON), mobile backhaul networks, radio access networks, multicast approaches and broadcast approaches in coordinated multipoint (CoMP) transmission/reception systems.

Recently, wavelength division multiplexing passive optical networks (WDM-PON) have attracted interest in fiber-to-the-home services because of their potential to deliver more than Gbps capacity to each subscriber. The application is also extended to future mobile backhaul networks for LTE-Advanced and beyond, as described by N.Cheng and F. Effenberger, "WDM-PON: Systems and Technologies", ECOC Workshop, Torino, Italy, 2010. For example, for coordinated multipoint systems (CoMP Systems) wavelength-division multiplexing passive optical networks is of interest.

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In accordance with the LTE-Advanced approach, each base station (BS), more precisely speaking each sector of a base station needs to support more than one Gbps transmission. Additional backhaul network capacity is necessary to support coordinated multi-point (CoMP) systems using multiple BSs to share the information and/or user data through mobile backhaul networks, as described by M.Sawahashi, Y. Kishiyama, A. Morimoto, D. Nishikawa and M. Tanno, "Coordinated multipoint transmission/reception techniques for LTE-advanced" IEEE wireless communications, vol. 17, issue 3, pp. 26 to 34, 2010. WDM-PON promises a virtually point-to-point link between a central node (OLT = optical line terminal) and a local node (ONU = optical network unit) by utilizing WDM techniques which is capable of providing several Gbps transmission to each ONU in which one base station with three or six sectors can be integrated.

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Fig. 1 depicts a schematic representation of a section of a wireless communication network used for implementing a coordinated multi-point system using a mobile backhaul network. The network 100 comprises a central switching terminal 102, also referred to as optical line terminal OLT. The network comprises a plurality of cells C_1 to C_5 each comprising a
5 respective base station BS_1 , BS_2 , BS_3 , BS_4 and BS_5 . Each of the base stations BS_1 to BS_5 is connected to a passive remote node 104 via a respective optical fiber connection 106_1 to 106_5 . The passive remote node 104 is coupled to the OLT 102 via an optical fiber 108. The OLT 102, the node 104 and the fibers 106_1 to 106_5 and 108 form the mobile backhaul network of the network 100. Fig. 1 shows a user equipment UE that, in accordance with the
10 coordinated multi-point approach, is served by three base stations BS_2 , BS_3 and BS_5 within the range (see circle 110) of the user equipment (see the respective arrows pointing from the base stations towards the user equipment).

Fig. 1 shows how CoMP operates with the support of the mobile backhaul network. For
15 CoMP joint processing techniques, multiple base stations jointly transmit downlink data to one or more UEs which allows to exploit higher multiplexing gain of MIMO systems by increasing the number of antennas. In order to support this approach, mobile backhaul networks provide user data to multiple base stations which cooperatively serve a single user equipment. For example, considering a situation as depicted in Fig. 1, when a further
20 user equipment is served by another subset of base stations, the respective base stations associated with the respective user equipment need to be provided with the necessary data for implementing the coordinated multipoint schemes. This requires multicasting approaches that allow transmitting data to multiple destinations. Besides the just-mentioned CoMP approach, there are several other applications that need multicasting capabilities, for
25 example paging and multimedia broadcast/multicast services MBMS. Thus, it would be desirable to use WDM-PON for mobile backhaul network applications to provide L1 layer (physical layer) multicasting.

While IP layer multicasting is known and may provide for the required functionality as L1
30 multicasting does, it cannot help multi-copy multicasting which needs to duplicate one multicasting packet into several packets. It cannot avoid causing larger network overhead which results in an inefficient network operation. The L1 layer multicasting is the most promising approach from the view point of network efficiency, and most of mobile backhaul network technologies such as digital subscriber line, T1, time-domain division passive
35 optical network (TDM-PON) do not have a problem to implement L1 multicasting/broadcasting because all local nodes share one physical medium (line) in such approaches.

However, this is not the case in WDM-PON in accordance with which each local node is allocated with one wavelength but not with a specific physical transmission medium.

A large number of publications exist that concern broadcasting functions in WDM-PON. One of the techniques that can be easily be implemented is to use a broad spectrum optical source, for example a light emitting diode, in the optical line terminal, as described by J. H. Moon, K. M. Choi and C. H. Lee, "Overlay of broadcasting signal in a WDM-PON", Optical Fiber Communication Conference, 2006.

Fig. 2 describes the architecture and functionality of a WDM-PON hardware, wherein Fig. 2(a) is a schematic representation of the hardware architecture and Fig. 2(b) and Fig. 2(c) describe the functionality of such an architecture in further detail. In Fig. 2(a) a schematic representation of the optical line terminal 102 is shown (also see Fig. 1) which is connected via the fiber 108 to the passive remote node 104 connected in turn via the respective optical fiber connections 106₁ to 106_N to the respective optical network units 112₁ to 112_N. The optical network units 112₁ to 112₆ comprise the respective base stations in a network as, for example, shown in Fig. 1. The passive remote node 104 comprises an arrayed waveguide grating (AWG) 114 having one OLT-side port 116 coupled to the fiber 108 connecting the node 104 to the OLT 102. Further, the AWG 114 comprises a plurality of ONU-side ports 118₁ to 118_N coupled to the respective fibers 106₁ to 106_N to be connected to the respective optical network units 112₁ to 112_N. The OLT 102 comprises a plurality of laser diodes 120₁ to 120_N each operating at a different wavelength λ_1 to λ_N , and each wavelength being associated with an optical receiver in one of the optical network units. For example, the laser diode 120₁ operates at a wavelength at which a photo detector in ONU 112₁ receives a signal. Likewise, the laser diode 120₂ operates at an optical wavelength at which a photo detector in ONU 112₂ receives light signals, and so on. The output ports of the respective laser diodes 120₁ to 120_N are coupled by an optical coupler 122 that is coupled to the fiber 108.

The functionality of the architecture depicted in Fig. 2(a) will now be described in further detail with regard to Figs. 2(b) and (c). In Fig. 2(b) it is desired to transmit data from the OLT 102 to the first ONU 112₁ (for example base station BS₁ in Fig. 1). The downlink data for ONU 112₁ is applied to laser diode 120₁ so that the light signal output by laser diode 120₁ is modulated with the downlink data to be provided to ONU 112₁. As depicted in Fig. 2(b), the signal output by the laser diode 120₁ is at a wavelength λ_1 and is passed from the output of the laser diode 120₁ via the coupler 122 and the fiber 108 to the OLT-side port 116 of the AWG 114 of the node 104. The AWG 114 causes the signal received at port 116 at the wavelength λ_1 to be forwarded to the ONU-side port 118₁ associated with

the first ONU 112₁ so that the signal at the wavelength λ_1 is coupled via the AWG 114 and the line 106₁ to the ONU 112₁ where the optical signal is received and demodulated for obtaining the downlink data 124₁ for further processing.

- 5 When it is desired to transmit data to other ONUs the respective laser diodes associated with the ONUs are provided with the respective downlink data, as depicted in Fig. 2(c). As can be seen, the respective laser diodes 120₁ to 120₃ operate at different wavelengths λ_1 to λ_3 at which the ONUs 112₁ to 112₃ are capable of receiving and demodulating signals. Via the couple 122, the fiber 108 and the AWG 114, in the above described way, the respective
10 signals are transmitted to the ONUs.

Thus, the WDM PON hardware architecture offers a point-to-point link between the OLT 102 and the respective ONUs 112₁ to 112_N. It is noted that for transmitting data in the uplink direction, i.e., from the ONUs to the OLT 102, the system basically operates in the
15 same way. The respective ONUs 112₁ to 112₆ also comprise laser diodes operating at respective wavelengths and the OLT comprises respective photo detectors for receiving signals from the different units 102₂ to 102₆.

The architecture shown in Fig. 2 with some minor modification also allows for implementing a broadcasting functionality, as will be described with regard to Fig. 3. When compared to Fig. 2, the OLT 102 further comprises a broadcasting block 126 and a further optical coupler 128 for coupling the signals output by the broadcasting block 126 into the fiber 108. The broadcasting block 126 comprises a broadband optical source 130, for example a light emitting diode, covering a wavelength range λ'_1 to λ'_6 outside the uplink and
20 downlink wavelength ranges indicated in Fig. 3 at the bottom. The respective ONUs 112₁ to 112_N comprise a photo detector capable of receiving an optical signal at one of the wavelengths provided by the source 130. The broadcasting block 126 further comprises a modulator 132 for modulating the output signal of the LED 130 with broadcast data to be transmitted to all ONUs 112₁ to 112_N. The modulated signal output from the block 126 is
25 coupled via the passive optical coupler 128 into the fiber 108 and is distributed via the AWG 114 to each of the ONUs 112₁ to 112_N which demodulates the signal for obtaining the broadcast data for further processing. The broad spectrum optical source 130 covers the entire wavelengths that WDM-PON uses so that it is possible to send one broadcasting data to all ONUs that belong to the OLT. In order to avoid a collision between the broadcasting
30 wavelength and the uplink and downlink wavelengths different wavelength bands may be used with a wavelength separation, wherein the wavelength separation from the uplink and downlink wavelength bands may correspond to the free spectral range (periodicity - FSR) of the AWG 114. In this case, each ONU comprises another photo detector together with a
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wavelength demultiplexer. This architecture provides not only for a very simple way to realize broadcasting in a WD-PON but also provides for the possibility to increase the downlink total capacity by including the broadcast channel as well as the original downlink channel.

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Thus, the approach according to Fig. 3 is fine for broadcasting data to all base stations of a network coupled to the OLT 102, however, this is not always needed, for example when considering a situation as depicted in Fig. 1, when a user equipment is served by two or more base stations. Fig. 4(a) shows a schematic representation of a network similar to the one in Fig. 1. A user equipment UE is within the range 134 of base stations BS₁ to BS₃ connected to the OLT 102. At the OLT 102 a data block 136 is provided which needs to be delivered to the base stations serving user equipment UE, namely base stations BS₁ to BS₃. Applying the functionality as described with regard to Fig. 3 results in a distribution of the data block 136 not only to base stations BS₁ to BS₃ but also to all other base stations in the network as depicted in Fig. 4(b), so that broadcasting delivers data to base stations which do not need it.

Thus, the broadcasting approach discussed above is useful to provide cable TV or broadcasting services to FTTH subscribers, however, it inherently has a limitation of use in mobile applications, namely the lack of multicasting capability. As described with regard to Fig. 4, for CoMP applications (see for example Fig. 1), not every base station joins CoMP, meaning the number of cooperative base stations is usually limited, wherein the actual number depends on several radio and network parameters. Moreover, as it shown in Fig. 5, it is likely to have a different cooperative group of base stations serving a different user equipment simultaneously in one PON system. More specifically, as shown in Fig. 5, user station UE₁ is served by base stations BS₁ to BS₃ as indicated by the arrows and the circle 134. A further base station UE₂ is present and is served, for example, only by base stations BS₄ and BS₅. Thus, the first group of base stations BS₁ to BS₃ serving user equipment UE₁ may require different information than the second group of base stations BS₄ and BS₅ serving user equipment UE₂. Thus, to provide different multicasting data to the different groups of base stations, a multicasting capability is required, not a broadcasting capability.

It is an object of the present invention to provide a novel WDM-PON architecture having L1 multicasting capabilities.

This object is achieved by a central node according to claim 1, a wireless communication system according to claim 11, an optical multiplexer/demultiplexer device according to

claim 12, a method according to claim 13 and a computer program product according to claim 15.

5 Embodiments of the invention provide a central node for a communication system having a plurality of nodes coupled to the central node by a passive optical network, the central node comprising:

an output port adapted to be coupled to the passive optical network; and

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a multiplexer/demultiplexer device having a plurality of outputs coupled to the output port,

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wherein the multiplexer/demultiplexer device is adapted to multiplex optical signals from a plurality of optical sources to one of the plurality of outputs, and to demultiplex an optical signal from a broad spectrum optical source to the plurality of outputs, and

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wherein for transmitting data to a group of nodes of the communication system, the central node is adapted to selectively provide the data at the output port using the optical signals at the plurality of outputs of the multiplexer/demultiplexer device.

Embodiments of the invention provide a wireless communication system, comprising:

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a plurality of nodes adapted to provide for a wireless communication with one or more wireless devices; and

at least one central node in accordance with embodiments of the invention,

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wherein the at least one central node and one or more of the plurality of nodes are coupled by a passive optical network forming the backhaul link between the central node and the nodes.

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Embodiments of the invention provide an optical multiplexer/demultiplexer device for a central node of a communication system having a plurality of nodes coupled to the central node by a passive optical network, the optical multiplexer/demultiplexer device comprising:

a plurality of inputs adapted to receive optical signals from a plurality of optical sources and an optical signal from a broad spectrum optical source;

a plurality of outputs, wherein the optical multiplexer/demultiplexer device is configured to multiplex the optical signals from the plurality of optical sources to one of the plurality of outputs, and wherein the optical multiplexer/demultiplexer device is configured to demultiplex the optical signal from the broad spectrum optical source into a plurality of optical signals having different wavelengths at the plurality of outputs;

a passive optical coupler adapted to couple the optical signals at the plurality of outputs to an output port; and

a plurality of devices coupled between respective ones of the plurality of outputs and the passive optical coupler, each of the plurality of devices being adapted to selectively provide data to be transmitted to a node of a group to the optical coupler.

Embodiments of the invention provide a method for transmitting data to one or more groups of nodes in a communication system having a plurality of nodes coupled to a central node by a passive optical network, the method comprising:

generating at the central node a broad spectrum optical signal;

selecting from the broad spectrum optical signal the wavelengths of which correspond to the wavelength allocated to the nodes in the one or more group; and

providing the data to the respective nodes in the one or more groups over the passive optical network using the selected optical signals.

Embodiments of the invention provide a computer program product comprising instructions stored by a machine readable carrier for carrying out the method in accordance with embodiments of the invention when executing the instructions on a computer.

In accordance with an embodiment the central node may comprise an optical coupler adapted to couple optical signals at the plurality of outputs of the multiplexer/demultiplexer device to the output port, and a plurality of devices coupled between the respective outputs of the multiplexer/demultiplexer device and the optical coupler, each of

the plurality of the devices being adapted to selectively provide data to be transmitted to a node of a group to the optical coupler.

In accordance with an embodiment the multiplexer/demultiplexer device is adapted to receive a modulated optical signal from the broad spectrum optical source, and to demultiplex the modulated optical signal to the plurality of outputs, the modulated optical signal comprising the data to be transmitted to a group of nodes in the communication system, and the central node is adapted to selectively couple the modulated optical signals to the output port.

In accordance with an embodiment the central node may comprise a broad spectrum optical source, a modulator having a first input coupled to an output of the broad spectrum optical source for receiving an unmodulated optical signal, a second input adapted to receive a modulation signal for modulating the optical signal with the data to be transmitted to the group of nodes, and an output coupled to the multiplexer/demultiplexer device and adapted to provide the modulated optical signal, and a plurality of optical switches, wherein an optical switch is provided between each of the plurality of outputs of the multiplexer/demultiplexer device and the output port, wherein the central node is adapted to control the plurality of optical switches such that only those modulated optical signals associated with the nodes in the group are forwarded to the output port.

In accordance with an embodiment the multiplexer/demultiplexer device is adapted to receive an unmodulated signal from the broad spectrum optical source, and to demultiplex the unmodulated signal to the plurality of outputs, and the central node is adapted to modulate those unmodulated optical signals at the plurality of outputs, which are associated with the nodes in the group, wherein the optical signals are modulated to comprise the data to be transmitted to the group of nodes. For transmitting first data to a first group of nodes and second data to a second group of nodes, the central node may be adapted to modulate a first set of optical signals at the plurality of outputs and associated with the nodes of the first group to comprise the first data, and to modulate a second set of optical signals at the plurality of outputs and associated with the nodes of the second group to comprise the second data.

In accordance with an embodiment the central node may further comprise a broad spectrum optical source coupled to the multiplexer/demultiplexer device for providing an unmodulated optical signal, and a plurality of modulators, wherein a modulator is provided between each of the plurality of outputs of the multiplexer/demultiplexer device and the output port, wherein the central node is adapted to selectively control the plurality of mod-

ulators to selectively modulate respective optical signals at the plurality of outputs to comprise data to be transmitted to one or more groups of nodes in the communication system.

5 In accordance with an embodiment each of the nodes in the communication system has allocated a different wavelength in the broad spectrum provided by the broad spectrum optical source and is adapted to detect an optical signal at the allocated wavelength, and wherein the multiplexer/demultiplexer device is adapted to demultiplex the optical signal received from the broad spectrum optical source into a plurality of optical signals, the demultiplexed optical signals having respective wavelengths corresponding to the wavelengths allocated to the respective nodes.
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In accordance with an embodiment the central node further comprises a plurality of optical sources adapted to provide respective optical signals at respective optical wavelengths allocated to the respective nodes in a communication system, wherein the multiplexer/demultiplexer device comprises a plurality of inputs for receiving the optical signals from the plurality of optical sources, and wherein the multiplexer/demultiplexer device is adapted to receive the optical signal from the broad spectrum optical source at one of the inputs also receiving an optical signal from one of the plurality of the optical sources, or to receive the optical signal from the broad spectrum optical source at an additional input.
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In accordance with an embodiment the multiplexer/demultiplexer device comprises an arrayed waveguide grating; the broad spectrum optical sources comprises a light emitting diode, and the optical sources comprise respective laser devices.

25 In accordance with an embodiment the method wherein selecting comprises modulating only those optical signals to comprise the data which have wavelengths allocated to the nodes of the one or more groups, or providing a modulated broad spectrum optical signal and forwarding only those wavelengths which correspond to the wavelengths allocated to the nodes in the group.
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Embodiments of the invention suggest a WDM-PON architecture having a L1 multicasting functionality. For a mobile backhaul radio access network supporting the LTE-Advanced standard and standards beyond, wavelength division multiplexing passive optical networks (WDM-PON) systems have been considered due to their capacity to offer a large link capacity. Such systems provide each local node with a dedicated optical wavelength which allows for a virtual point-to-point link between a central node and a local node. This allows to provide a multi Gbps backhaul link capacity to each base station whose bandwidth re-
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quirement is more than one Gbps. Because of this point-to-point link characteristic, it is difficult to realize physical layer (L1) multicasting on top of the WDM-PONs. In addition to the delivering broadcasting services, a mobile cellular network also includes applications that need multicasting, for example a coordinated multipoint (CoMP) system which
5 needs multicasting transmission to only specific base stations that have joined the CoMP. In accordance with the inventive approach, different multicasting data can be provided to different groups of base stations allowing for a more efficient use of network resources when compared to broadcasting. In accordance with embodiments, a broad spectrum optical source is used together with multiple optical modulators or switches for multicasting
10 the signal transmission. Apart from the above mentioned components, the WDM-PON architecture in accordance with embodiments corresponds to the conventional architecture, so that in accordance with the inventive approach a cost-effective solution for multicasting over WDM-PON is provided.

15 Embodiments of the invention are advantageous as they allow for providing a desired multicasting functionality. While broadcasting offers transmitting the same data to all optical network units without intelligence to selectively choose optical network units which actually need such broadcasting signals, multicasting enables to transmit data to only those optical network units which need the signals resulting in a more efficient use of the back-
20 haul network. In addition, it is possible to provide multiple multicasting groups with the different multicasting data, and this is particularly useful in CoMP applications. Compared with IP multicasting, L1 multicasting in accordance with the inventive approach in the physical layer enables single-copy multicasting, which will not increase the network overhead as IP multicasting does.

25 A further advantage of the inventive approach is that an additional flexibility in the downlink channel capacity is generated. An additional wavelength band for multicasting optical channels is provided which is separated from the downlink data channel in the WDM-PON system. Thus, when there is a need to have a larger downlink capacity, for example for
30 specific CoMP applications, the multicasting channel may be used to increase also the downlink capacity. This allows for a reconfiguration capability of backhaul networks which, in turn, allows to control/manage backhaul networks more efficiently.

35 Embodiments of the present invention will now be described with regard to the accompanying drawings, in which:

- Fig. 1 depicts a schematic representation of a section of a wireless communication network used for implementing a coordinated multi-point system using mobile backhaul networks;
- 5 Fig. 2 describes the architecture and functionality of a WDM-PON hardware, wherein Fig. 2(a) is a schematic representation of the hardware architecture, and wherein Fig. 2(b) and Fig. 2(c) describe the functionality of the architecture of Fig. 2(a) in further detail;
- 10 Fig. 3 depicts an architecture similar to the one shown in Fig. 2 with some minor modification for implementing a broadcasting functionality;
- Fig. 4 shows a schematic representation of a network similar to the one in Fig. 1, wherein Fig. 4(a) shows a data block for delivery to a group of base stations at the OLT, and wherein Fig. 4(b) shows that applying the functionality as described with regard to Fig. 3 results in a distribution of the data block to all
15 base stations in the network;
- Fig. 5 shows different cooperative groups of base stations serving different user equipments simultaneously in one PON system;
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- Fig. 6 shows a WDM-PON architecture having multicasting capabilities in accordance with an embodiment of the invention;
- 25 Fig. 7 shows a WDM-PON architecture in accordance with another embodiment of the invention having multicasting capabilities that allow to have different multicasting groups in a PON;
- Fig. 8 shows the architecture depicted in Fig. 7 allowing to selectively modulate multicasting data, wherein Fig. 8(a) shows multicasting data only to one group, and wherein Fig. 8(b) shows multicasting different data to different groups;
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- Fig. 9 shows a WDM-PON architecture in accordance with yet another embodiment of the invention providing for multicasting capabilities that allow one multicasting group in a PON;
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- Fig. 10 shows the effects of multicasting data in accordance with embodiments of the invention, wherein Fig. 10(a) shows a schematic view of a wireless communi-

cation network having base stations serving different user equipments, and wherein Fig. 10(b) shows that data blocks are forwarded only to the base stations which need the data; and

- 5 Fig. 11 shows an evaluation of how multicasting can enhance the network MIMO plus the feasibility.

10 Fig. 6 shows a WDM-PON architecture having multicasting capabilities in accordance with an embodiment of the invention. In Fig. 6 only the optical line terminal 102 is depicted; those elements that have been described already with regard to the preceding figures are associated with the same reference number and will not be described again. In Fig. 6 only the OLT 102 coupled to the fiber 108 is shown as the rest of the system remains unchanged. As can be seen from a comparison of Figs. 3 and 6, the OLT 102 comprises the
15 plurality of laser diodes 120_1 to 120_4 and also the block 126 comprising the broad spectrum optical source 130, for example a LED and the modulator 132. In addition to the arrangement depicted with regard to Fig. 3, the architecture in accordance with the embodiment of Fig. 6 comprises an NxN arrayed wave guide grating (AWG) 140 having a plurality of input ports 142_1 to 142_5 and a plurality of output ports 144_1 to 144_5 . The output of the
20 laser diodes 120_1 to 120_4 are coupled to the respective input ports 142_2 to 142_5 wherein the AWG 140 is configured to apply the signals at the input ports 142_2 to 142_5 to a common output port 144_5 . The output of the block 126 is coupled to the input port 142_1 and the AWG 140 is configured to distribute wavelengths of the broadband signal to the respective output ports 144_1 to 144_5 . The OLT 102 in addition comprises a plurality of modulators or
25 switches 146_1 to 146_5 having an input coupled to the respective output ports 144_1 to 144_5 of the AWG 140 and having the output coupled to the passive optical coupler 128 which, in turn, is coupled to the fiber 108.

30 The components used in the architecture in accordance with the embodiment of Fig. 6 are commercially available and fully compliant with conventional WDM-PON systems, so that the embodiment according to Fig. 6 allows for a cost-effective solution. The basic idea of the approach in accordance with the embodiment of Fig. 6 is to use a different arrayed wave guide grating when compared to prior art approaches and to provide the additional modulators/switches. More specifically, in accordance with the inventive approach as depicted in the embodiment of Fig 6, instead of using a Nx1 arrayed wave guide grating as is
35 used in Fig. 3 for coupling the signals from the laser diodes (N inputs) to a common output (1 output), a NxN AWG 140 (N inputs – N outputs) is used to separate the different wavelengths from the broad spectrum optical source 130, for example the LED. Further, the

modulators/switches 146₁ to 146₄ are provided for each wavelength at the output of the NxN AWG 140. In a similar way as the broadcasting approach described above, the inventive approach utilizes the LED 130 to generate broad spectrum optical signals having a wavelength λ'_1 to λ'_4 which are at a different band when compared to the wavelength of the optical signal for the downlink so that the wavelength ranges are separated by the FSR of the AWG 140. By means of the AWG characteristics, the broad spectrum optical signals are spatially separated at the output of the AWG 140 according to their wavelength. The AWG 140 will also be used for multiplexing and demultiplexing downlink/uplink optical signals exchanged between the OLT 102 and the respective ONUs. At each output of the AWG 140 the optical modulator or switch 146₁ to 146₅ is provided, and the outputs are combined to a main downlink port by using the passive optical coupler 128.

As shall be described in further detail below, the use of optical modulators enables to apply different multicasting data into different wavelengths allocated with different ONUs, while a simpler approach uses only optical switches instead of the modulators to simply block transmissions to ONUs that do not need to get multicasting data.

Fig. 7 shows a WDM-PON architecture in accordance with another embodiment of the invention having multicasting capabilities that allow to have different multicasting groups in a PON similar to Fig. 6 except that elements 146₁ to 146₅ are respective modulators, and element 132 is a control block. Also the AWG is slightly different in that it comprises a number of inputs 142₁ to 142₅ and outputs 144₁ to 144₅ corresponding the number of laser diodes 120₁ to 120₅ (in Fig. 7 there are five inputs and five outputs). The signal from the multicast block 126 is coupled via the coupler 147 into the first input 142₁ also used for the signals from the first laser diode 120₁. The multicasting block 126 comprises the broad spectrum optical source 130 and the control block 132 receiving the multicasting data. The output of the control block 132 is connected to the plurality of modulators 146₁ to 146₅ coupled to the output ports of the AWG 140. The architecture depicted in Fig. 7 makes it possible to selectively modulate different multicasting data into different ONUs. This is described in further detail with regard to Fig. 8. In Fig. 8(a) a situation is assumed in accordance with which multicast data is to be transmitted only to ONUs 112₁ and 112₂. The respective data is provided to the control block or multiplexer 132 of the multicasting block of the OLT 102. The signal received at the multiplexer 132 indicates that the signals are desired to be forwarded to the group comprising the ONUs 112₁ and 112₂ so that the data provided is forwarded by block 132 only to the optical modulators 146₁ and 146₂. The signals at wavelengths λ'_1 and λ'_2 provided by the broad LED 130 are modulated with the multicast data, while the remaining signals at the optical wavelengths λ'_3 to λ'_N are not modulated. Thus, only ONUs 112₁ and 112₂ receive the optical signals from the LED 130

at wavelengths with the multicast data is modulated thereto so that the respective multicast data is output for further transmission by the ONUs 112₁ and 112₂. The remaining ONUs do not receive modulated signals so that no signals are derived.

Fig. 8(b) shows a similar approach as in Fig. 8(a) except that different multicast data is to be transmitted to different sets of ONUs. More specifically, at the multiplexer 132 of the multicast block 126 of the OLT 102 respective multicast data for two groups are received indicating to the multiplexer 132 which of the ONUs is part of the respective groups. On the basis of this information the multiplexer 132 forwards the data for the multicast group #1 to the optical modulators 146₁ and 146₂, and the multicast data for group #2 to the optical modulators 146₄ and 146₅. Thus, the signals at wavelengths λ'_1 and λ'_2 are modulated with the data for the multicast group 1, and the signals at wavelengths λ'_4 and λ'_5 are modulated with the multicast data for group 2. The signals are transmitted to the ONUs as described above with regard to the broadcasting approach, however only the ONUs 112₁ and 112₂ as well as the ONUs 112₄, 112₅ receive modulated signals at the just mentioned wavelengths and therefore receive the multicast data for group #1 (see reference sign 150₁) and for group #2 (see reference sign 150₂). The remaining ONUs 112₃ and 112₆ receive no optical signal by blocking transmission in modulators, and therefore provide no data at their output.

Fig. 9 shows a WDM-PON architecture in accordance with yet another embodiment of the invention providing for multicasting capabilities that allow one multicasting group in a PON. The structure of the OLT 102 corresponds to the structure described with regard to Fig. 7 except that the elements 146₁ to 146₅ are optical switches. In accordance with the embodiment depicted in Fig. 9, multicasting data may be submitted to one or more of the ONUs 112₁ to 112₆. For example, when it is desired to multicast data only to ONUs 112₁ and 112₂ the desired multicasting data is modulated onto the output signal of the LED 130 using the modulator 132 and, via the AWG 140 this signal is supplied to the respective output ports 144₁ to 144₅. The optical switches are controlled dependent on which of the ONUs is to receive the multicast data. For example, when only ONUs 112₁ and 112₃ should receive the multicast data, optical switches 146₁ and 146₃ are activated to allow the signals output from the AWG 140 to pass, thereby only providing signals with the wavelength λ'_1 and λ'_3 which are detected by the ONUs 112₁ and 112₃. The other ONUs do not receive signals at the wavelengths allocated with them for receiving multicast data. Thus, Fig. 9 describes an embodiment of WDM-PON architecture with multicasting functionality limited to only one group in the WDM-PON. The broad spectrum optical source 130, like a LED, is used and modulated with a multicasting data by using an external modulator 132, for example an electro absorption modulator. The modulated optical signals are fed into the

first port of the NxN passive wavelength router (e.g. an AWG) 140 which is originally used for multiplexing and demultiplexing of downlink and uplink optical signals. The multicasting optical signals having the broad spectrum are spatially separated at the outputs of the AWG 140. A multicasting transmission is blocked by the optical switches for those
5 ONUs which do not need multicasting data.

The effects of multicasting data will be described with regard to Fig. 10 in which an OLT in accordance with Fig. 7 is assumed, i.e. an OLT allowing to have different multicasting groups in a PON. Fig. 10(a) shows a situation similar to Fig. 4 and Fig. 5. More specifically, Fig. 10(a) shows a schematic view of a wireless communication network having a plu-
10 rality of cells with respective base stations. It is assumed that a first user equipment UE_1 is served by base stations BS_1 to BS_3 as depicted by circle 134. A second user equipment UE_2 is served by base stations BS_4 and BS_5 as depicted by circle 134'. It is assumed that the system uses CoMP for serving the user equipments by different base stations. The base
15 stations BS_1 and BS_5 are connected via the WDM-PON to the OLT 102 at which respective multicast data blocks 136₁ and 136₂ are provided for transmission to the respective user equipments. Block 136₁ is associated with user equipment UE_1 and block 136₂ is associated with user equipment UE_2 .

Applying the inventive approach in accordance with the embodiment of Figs. 7 and 8, a situation as shown in Fig. 10(b) is achieved in which the respective data blocks 136₁ and 136₂ are forwarded only to the base stations of groups 134 and 134', respectively. To be more specific, base stations BS_1 to BS_3 receive the data block 136₁ while the base stations BS_4 and BS_5 receive the data block 136₂. Base stations BS_6 to BS_9 do not receive any data
25 blocks. Thus, Fig. 10 depicts the efficiency of the inventive approach for multicasting data to different groups in a WDM-PON system.

Fig. 11 shows an evaluation of how multicasting can enhance the network MIMO plus the feasibility. Fig. 11 shows that multicasting increases the cluster feasibility of network MI-
30 MO, which in turn results in an improved user throughput.

Although some aspects have been described in the context of an apparatus, it is clear that these aspects also represent a description of the corresponding method, where a block or device corresponds to a method step or a feature of a method step. Analogously, aspects
35 described in the context of a method step also represent a description of a corresponding block or item or feature of a corresponding apparatus.

Depending on certain implementation requirements, embodiments of the invention can be implemented in hardware or in software. The implementation can be performed using a digital storage medium, for example a floppy disk, a DVD, a CD, a ROM, a PROM, an EPROM, an EEPROM or a FLASH memory, having electronically readable control signals stored thereon, which cooperate (or are capable of cooperating) with a programmable computer system such that the respective method is performed. Some embodiments according to the invention comprise a data carrier having electronically readable control signals, which are capable of cooperating with a programmable computer system, such that one of the methods described herein is performed. Generally, embodiments of the present invention can be implemented as a computer program product with a program code, the program code being operative for performing one of the methods when the computer program product runs on a computer. The program code may for example be stored on a machine readable carrier. Other embodiments comprise the computer program for performing one of the methods described herein, stored on a machine readable carrier.

In other words, an embodiment of the inventive method is, therefore, a computer program having a program code for performing one of the methods described herein, when the computer program runs on a computer. A further embodiment of the inventive methods is, therefore, a data carrier (or a digital storage medium, or a computer-readable medium) comprising, recorded thereon, the computer program for performing one of the methods described herein. A further embodiment of the inventive method is, therefore, a data stream or a sequence of signals representing the computer program for performing one of the methods described herein. The data stream or the sequence of signals may for example be configured to be transferred via a data communication connection, for example via the Internet. A further embodiment comprises a processing means, for example a computer, or a programmable logic device, configured to or adapted to perform one of the methods described herein. A further embodiment comprises a computer having installed thereon the computer program for performing one of the methods described herein.

In some embodiments, a programmable logic device (for example a field programmable gate array) may be used to perform some or all of the functionalities of the methods described herein. In some embodiments, a field programmable gate array may cooperate with a microprocessor in order to perform one of the methods described herein. Generally, the methods are preferably performed by any hardware apparatus.

The above described embodiments are merely illustrative for the principles of the present invention. It is understood that modifications and variations of the arrangements and the details described herein will be apparent to others skilled in the art. It is the intent, there-

fore, to be limited only by the scope of the impending patent claims and not by the specific details presented by way of description and explanation of the embodiments herein.

CLAIMS

1. A central node (102) for a communication system (100) having a plurality of nodes (BS₁-BS₉, 112₁-112_N) coupled to the central node (102) by a passive optical network (104, 106₁-106_N, 108), the central node (102) comprising:

an output port adapted to be coupled to the passive optical network (104, 106₁-106_N, 108); and

a multiplexer/demultiplexer device (140) having a plurality of outputs (144₁-144_N) coupled to the output port,

wherein the multiplexer/demultiplexer device (140) is adapted to multiplex optical signals from a plurality of optical sources (120₁-120_N) to one (144₅, 144_N) of the plurality of outputs (144₁-144_N), and to demultiplex an optical signal from a broad spectrum optical source (130) to the plurality of outputs (144₁-144_N), and

wherein for transmitting data to a group of nodes (BS₁-BS₉, 112₁-112_N) of the communication system (100), the central node (102) is adapted to selectively provide the data at the output port using the optical signals at the plurality of outputs (144₁-144_N) of the multiplexer/demultiplexer device (140).

2. The central node (102) of claim 1, comprising:

an optical coupler (128) adapted to couple optical signals at the plurality of outputs (144₁-144_N) of the multiplexer/demultiplexer device to the output port; and

a plurality of devices (146₁-146_N) coupled between the respective outputs (144₁-144_N) of the multiplexer/demultiplexer device (140) and the optical coupler (128), each of the plurality of devices (146₁-146_N) being adapted to selectively provide data to be transmitted to a node of a group to the optical coupler (128).

3. The central node (102) of claim 1 or 2, wherein

the multiplexer/demultiplexer device (140) is adapted to receive a modulated optical signal from the broad spectrum optical source (130), and to demultiplex the modulated optical signal to the plurality of outputs (144₁-144_N), the modulated opt-

ical signal comprising the data to be transmitted to a group of nodes (BS_1 - BS_9 , 112_1 - 112_N) in the communication system (100), and

the central node (102) is adapted to selectively couple the modulated optical signals to the output port.

4. The central node (102) of one of claims 1 to 3, comprising:

a broad spectrum optical source (130);

a modulator (132) having a first input coupled to an output of the broad spectrum optical source (130) for receiving an unmodulated optical signal, a second input adapted to receive a modulation signal for modulating the optical signal with the data to be transmitted to the group of nodes, and an output coupled to the multiplexer/demultiplexer device (140) and adapted to provide the modulated optical signal; and

a plurality of optical switches (146_1 - 146_N), wherein an optical switch (146_1 - 146_N) is provided between each of the plurality of outputs (144_1 - 144_N) of the multiplexer/demultiplexer device (140) and the output port,

wherein the central node (102) is adapted to control the plurality of optical switches (146_1 - 146_N) such that only those modulated optical signals associated with the nodes in the group are forwarded to the output port.

5. The central node (102) of claim 1 or 2, wherein

the multiplexer/demultiplexer device (140) is adapted to receive an unmodulated signal from the broad spectrum optical source (130), and to demultiplex the unmodulated signal to the plurality of outputs (144_1 - 144_N), and

the central node (102) is adapted to modulate those unmodulated optical signals at the plurality of outputs (144_1 - 144_N), which are associated with the nodes (BS_1 - BS_9 , 112_1 - 112_N) in the group, wherein the optical signals are modulated to comprise the data to be transmitted to the group of nodes.

6. The central node (102) of claim 5, wherein for transmitting first data to a first group of nodes and second data to a second group of nodes, the central node (102) is

adapted to modulate a first set of optical signals at the plurality of outputs (144₁-144_N) and associated with the nodes of the first group to comprise the first data, and to modulate a second set of optical signals at the plurality of outputs (144₁-144_N) and associated with the nodes of the second group to comprise the second data.

5

7. The central node (102) of one of claims 1, 2, 5 or 6, comprising:

a broad spectrum optical source (130) coupled to the multiplexer/demultiplexer device (140) for providing an unmodulated optical signal; and

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a plurality of modulators (146₁-146_N), wherein a modulator (146₁-146_N) is provided between each of the plurality of outputs (144₁-144_N) of the multiplexer/demultiplexer device (140) and the output port,

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wherein the central node (102) is adapted to selectively control the plurality of modulators (146₁-146_N) to selectively modulate respective optical signals at the plurality of outputs (144₁-144_N) to comprise data to be transmitted to one or more groups of nodes in the communication system (100).

20

8. The central node (102) of one of claims 1 to 7, wherein each of the nodes (BS₁-BS₉, 112₁-112_N) in the communication system (100) has allocated a different wavelength in the broad spectrum provided by the broad spectrum optical source (130) and is adapted to detect an optical signal at the allocated wavelength, and wherein the multiplexer/demultiplexer device (140) is adapted to demultiplex the optical signal received from the broad spectrum optical source (130) into a plurality of optical signals, the demultiplexed optical signals having respective wavelengths corresponding to the wavelengths allocated to the respective nodes (BS₁-BS₉, 112₁-112_N).

25

9. The central node (102) of one of claims 1 to 8, comprising:

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a plurality of optical sources (120₁-120_N) adapted to provide respective optical signals at respective optical wavelengths allocated to the respective nodes (BS₁-BS₉, 112₁-112_N) in a communication system (100),

35

wherein the multiplexer/demultiplexer device (140) comprises a plurality of inputs for receiving the optical signals from the plurality of optical sources (120₁-120_N), and

wherein the multiplexer/demultiplexer device (140) is adapted to receive the optical signal from the broad spectrum optical source (130) at one of the inputs also receiving an optical signal from one of the plurality of the optical sources (120₁-120_N), or to receive the optical signal from the broad spectrum optical source (130) at an additional input.

10. The central node (102) of one claims 1 to 9, wherein

the multiplexer/demultiplexer device (140) comprises an arrayed waveguide grating;

the broad spectrum optical source (130) comprises a light emitting diode, and

the optical sources (120₁-120_N) comprise respective laser devices.

11. A wireless communication system (100), comprising:

a plurality of nodes (BS₁-BS₉, 112₁-112_N) adapted to provide for a wireless communication with one or more wireless devices; and

at least one central node (102) as defined in one of claims 1 to 10,

wherein the at least one central node (102) and one or more of the plurality of nodes (BS₁-BS₉, 112₁-112_N) are coupled by a passive optical network (104, 106₁-106_N, 108) forming the backhaul link between the central node (102) and the nodes (BS₁-BS₉, 112₁-112_N).

12. An optical multiplexer/demultiplexer device (140) for a central node (102) of a communication system (100) having a plurality of nodes (BS₁-BS₉, 112₁-112_N) coupled to the central node (102) by a passive optical network (104, 106₁-106_N, 108), the optical multiplexer/demultiplexer device (140) comprising:

a plurality of inputs adapted to receive optical signals from a plurality of optical sources (120₁-120_N) and an optical signal from a broad spectrum optical source (130);

a plurality of outputs (144₁-144_N), wherein the optical multiplexer/demultiplexer device (140) is configured to multiplex the optical signals from the plurality of opt-

ical sources (120₁-120_N) to one of the plurality of outputs (144₅, 144_N), and wherein the optical multiplexer/demultiplexer device (140) is configured to demultiplex the optical signal from the broad spectrum optical source (130) into a plurality of optical signals having different wavelengths at the plurality of outputs (144₁-144_N);

a passive optical coupler (128) adapted to couple the optical signals at the plurality of outputs (144₁-144_N) to an output port; and

a plurality of devices (146₁-146_N) coupled between respective ones of the plurality of outputs (144₁-144_N) and the passive optical coupler (128), each of the plurality of devices (146₁-146_N) being adapted to selectively provide data to be transmitted to a node of a group to the optical coupler (128).

13. A method for transmitting data to one or more groups of nodes (BS₁-BS₉, 112₁-112_N) in a communication system (100) having a plurality of nodes (BS₁-BS₉, 112₁-112_N) coupled to a central node (102) by a passive optical network (104, 106₁-106_N, 108), the method comprising:

generating at the central node (102) a broad spectrum optical signal;

selecting from the broad spectrum optical signal those optical signals the wavelengths of which correspond to the wavelength allocated to the nodes in the one or more group; and

providing the data to the respective nodes in the one or more groups over the passive optical network (104, 106₁-106_N, 108) using the selected optical signals.

14. A method of claim 14, wherein selecting comprises:

modulating only those optical signals to comprise the data which have wavelengths allocated to the nodes of the one or more groups, or

providing a modulated broad spectrum optical signal and forwarding only those wavelengths which correspond to the wavelengths allocated to the nodes in the group.

15. A computer program product comprising instructions stored by a machine readable carrier for carrying out the method of claim 13 or 14 when executing the instructions on a computer.

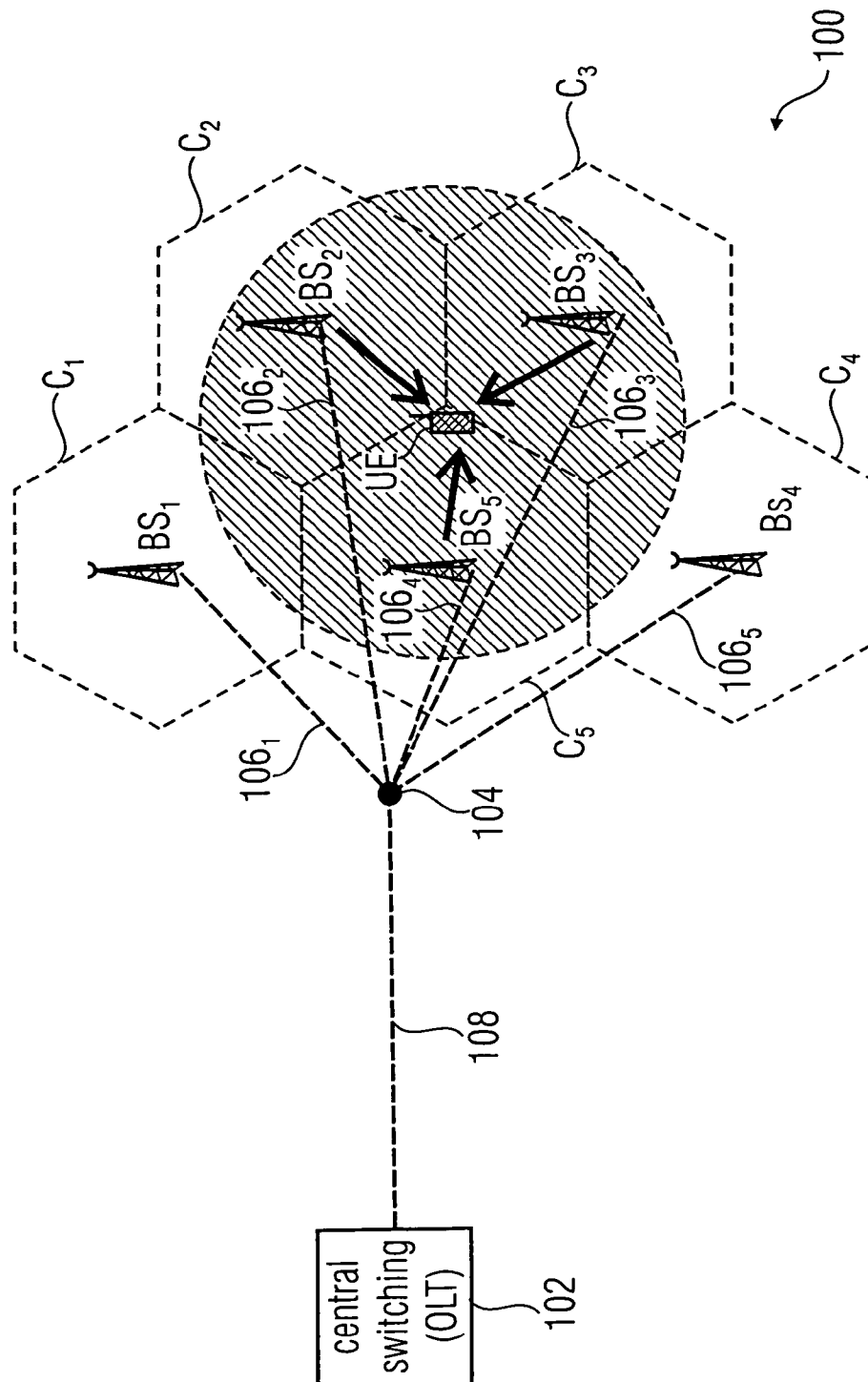


FIG 1

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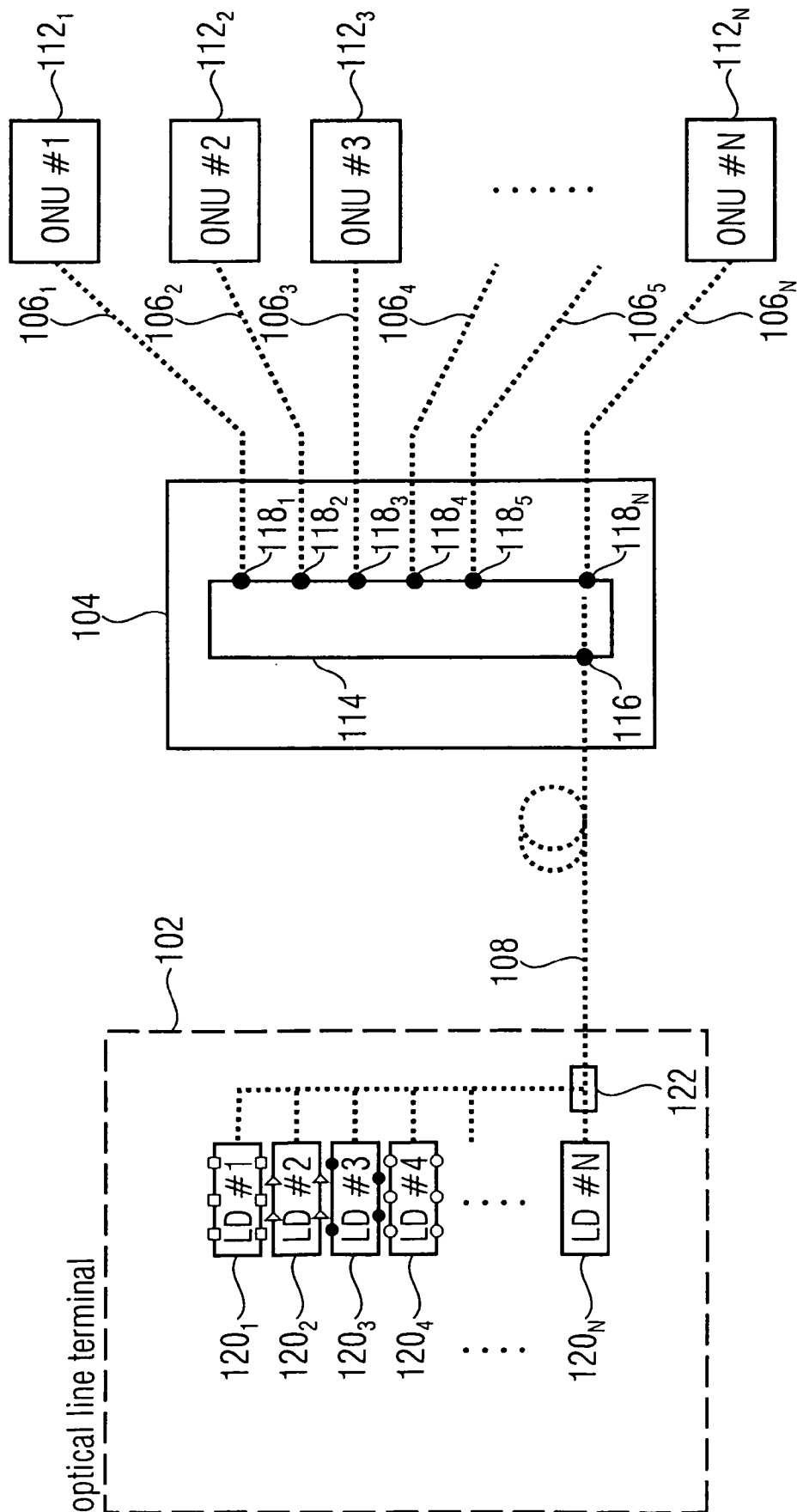


FIG 2A

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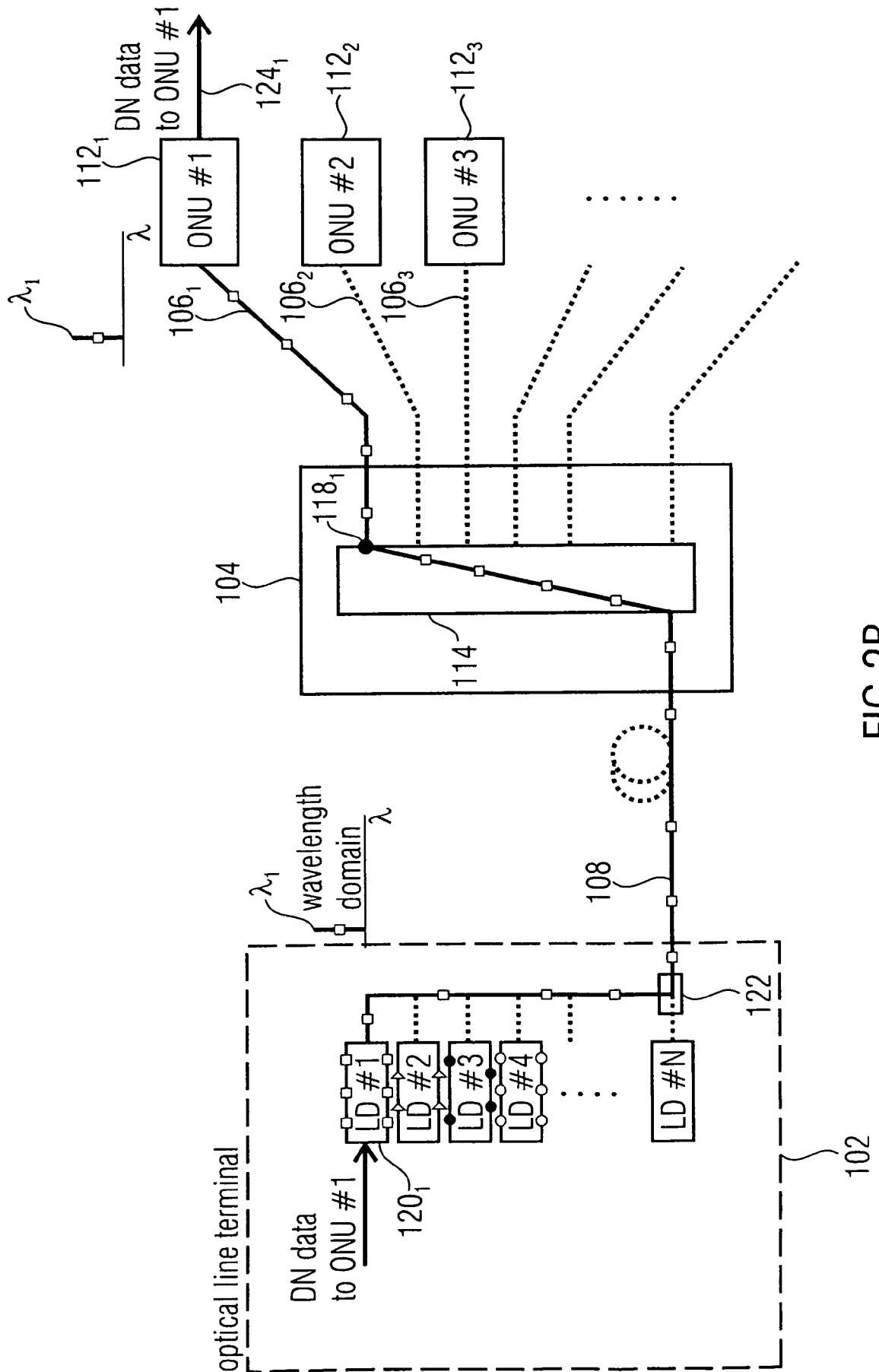


FIG 2B

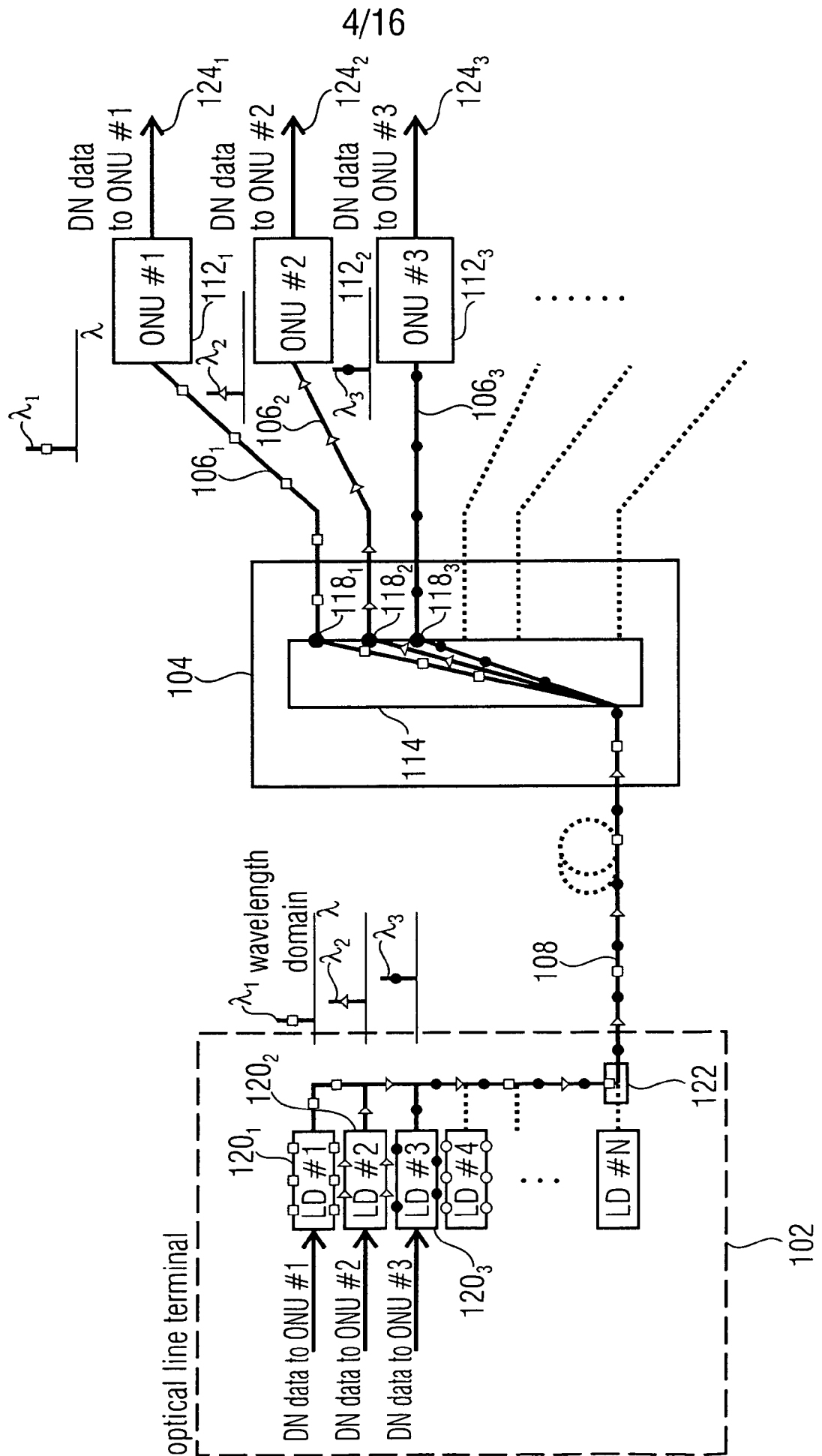


FIG 2C

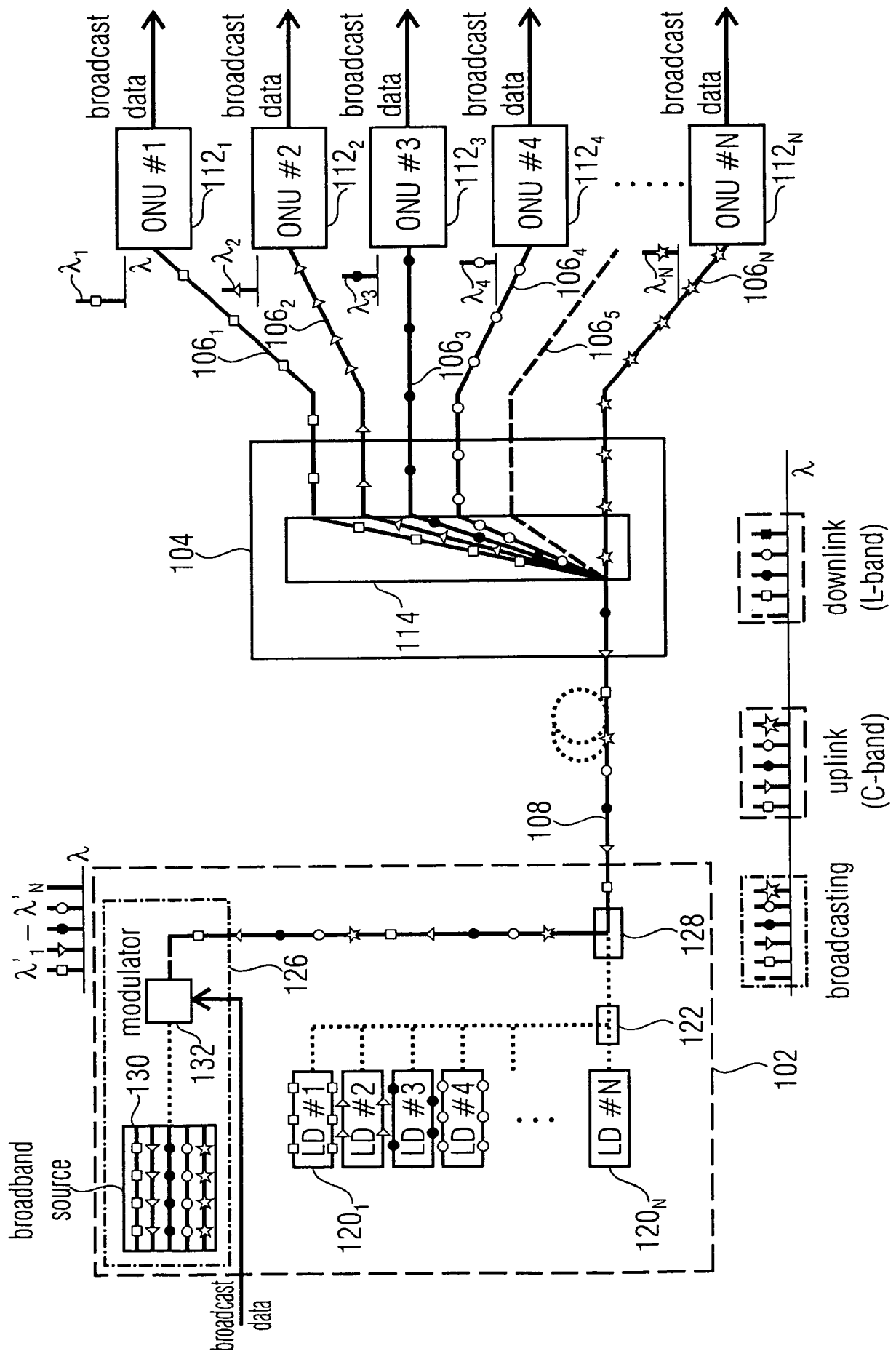


FIG 3

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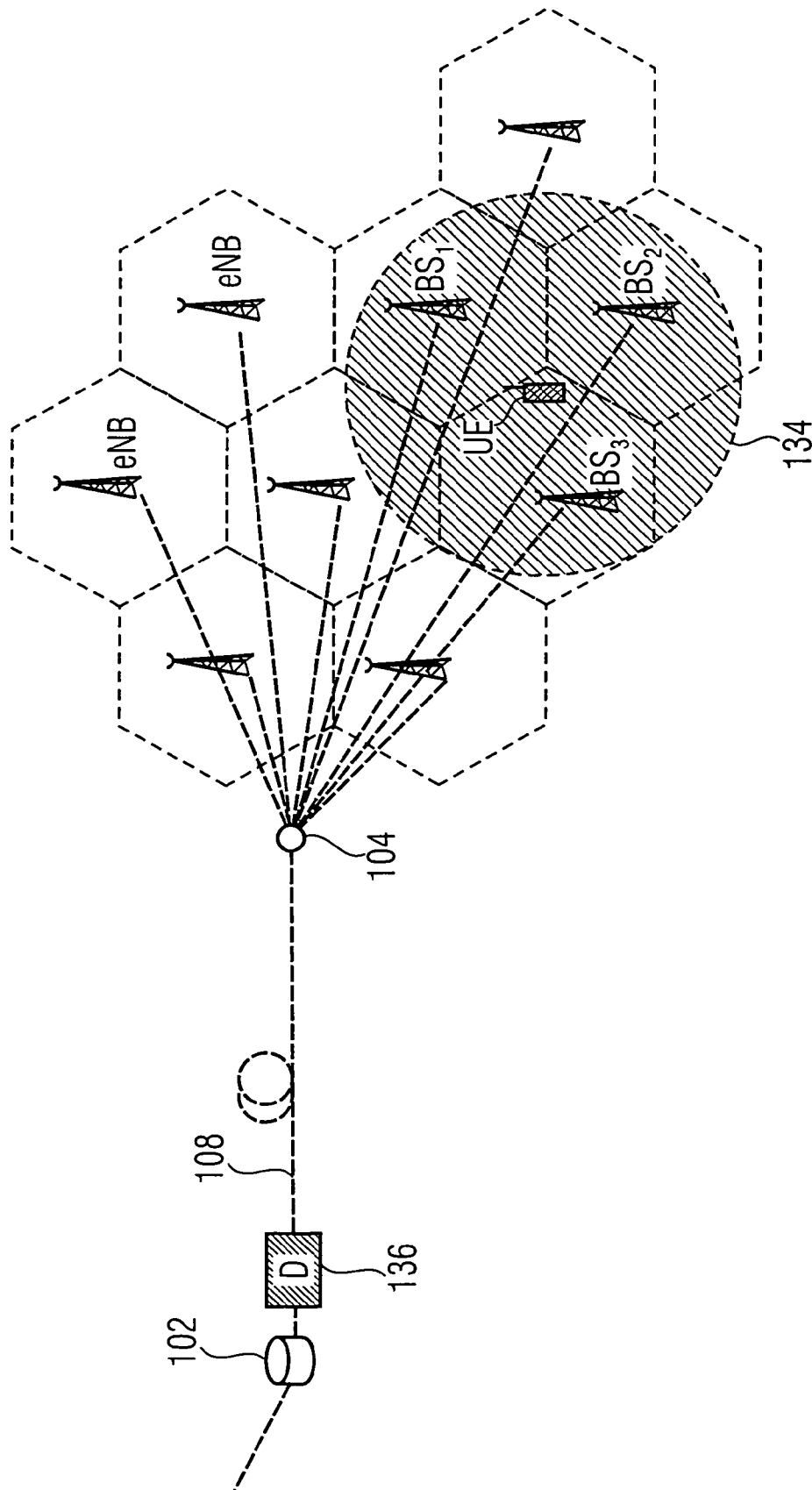


FIG 4A

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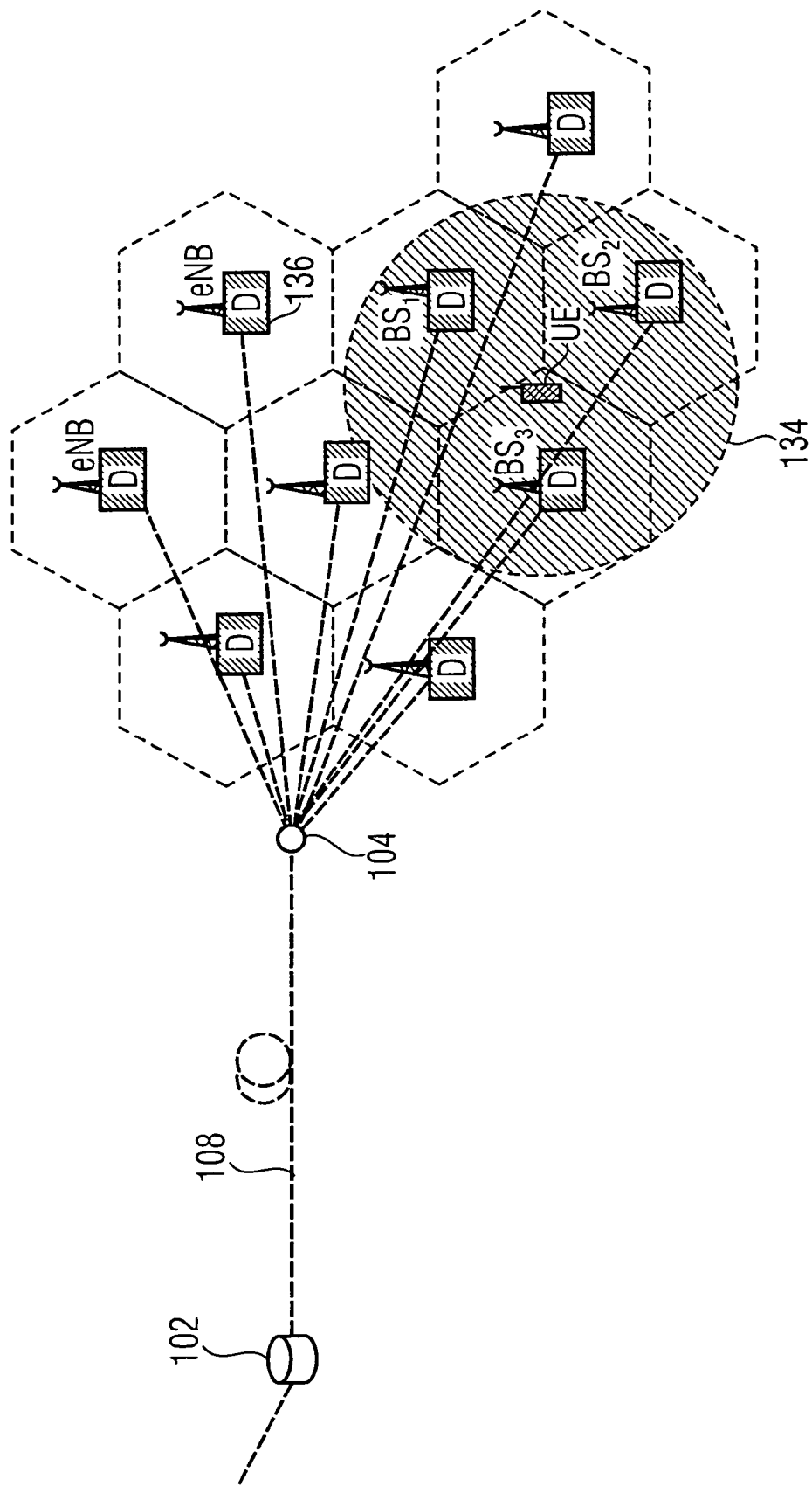


FIG 4B

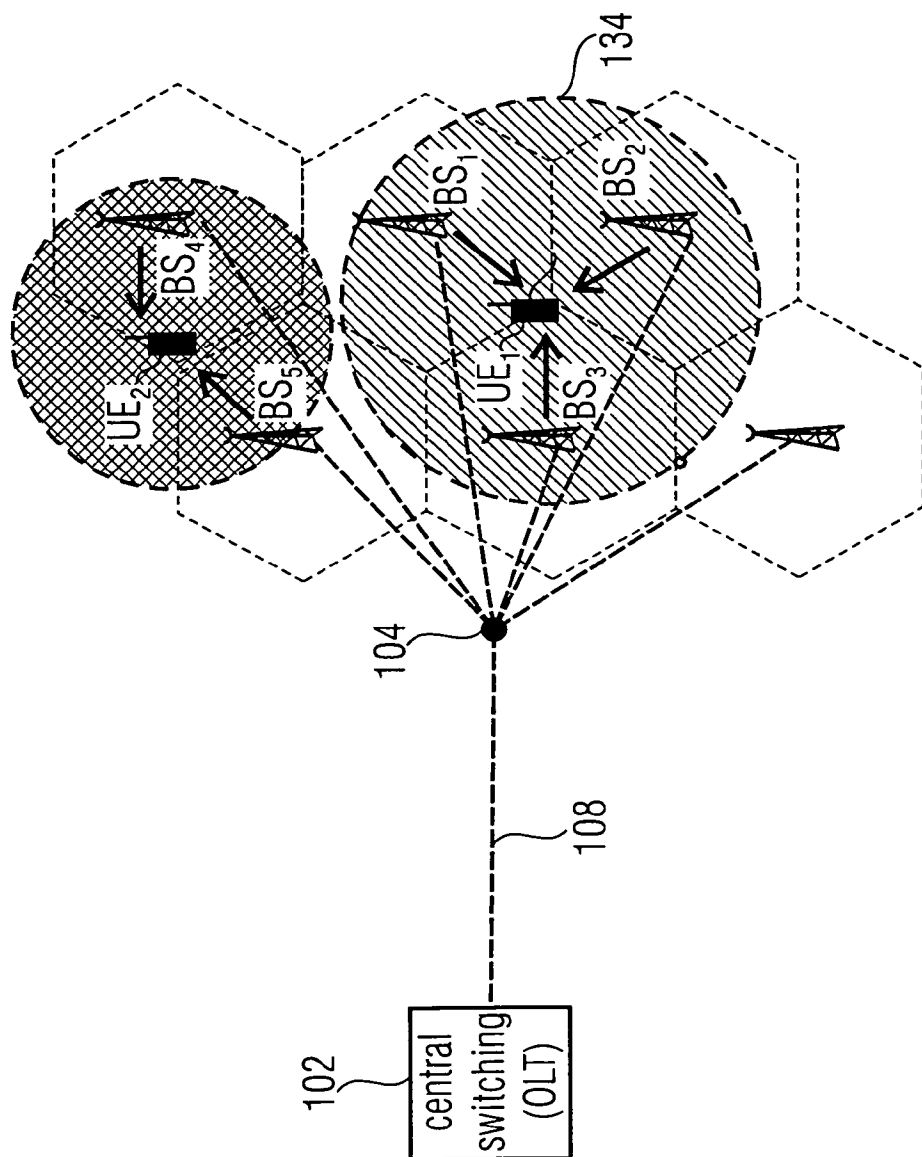


FIG 5

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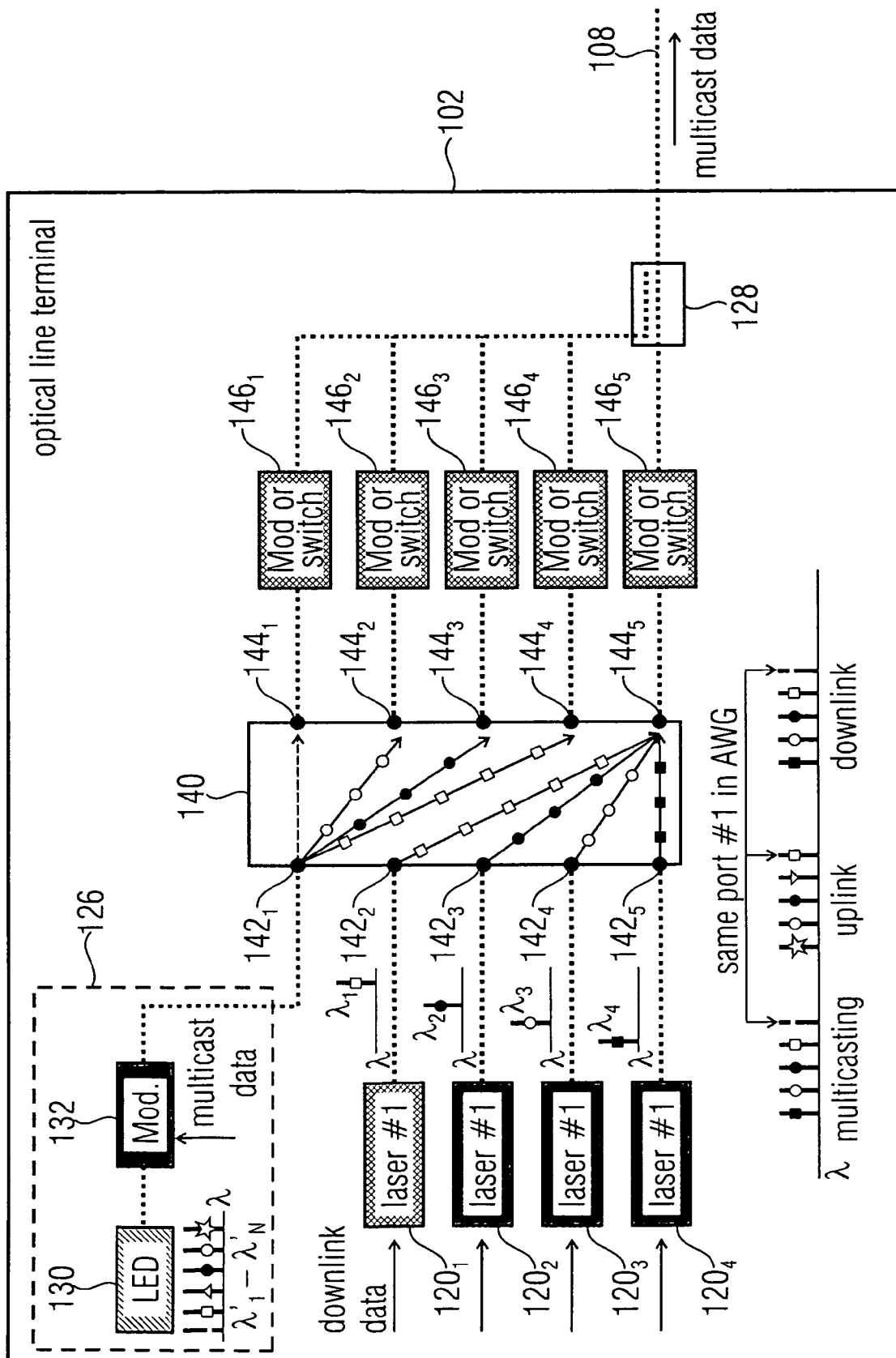


FIG 6

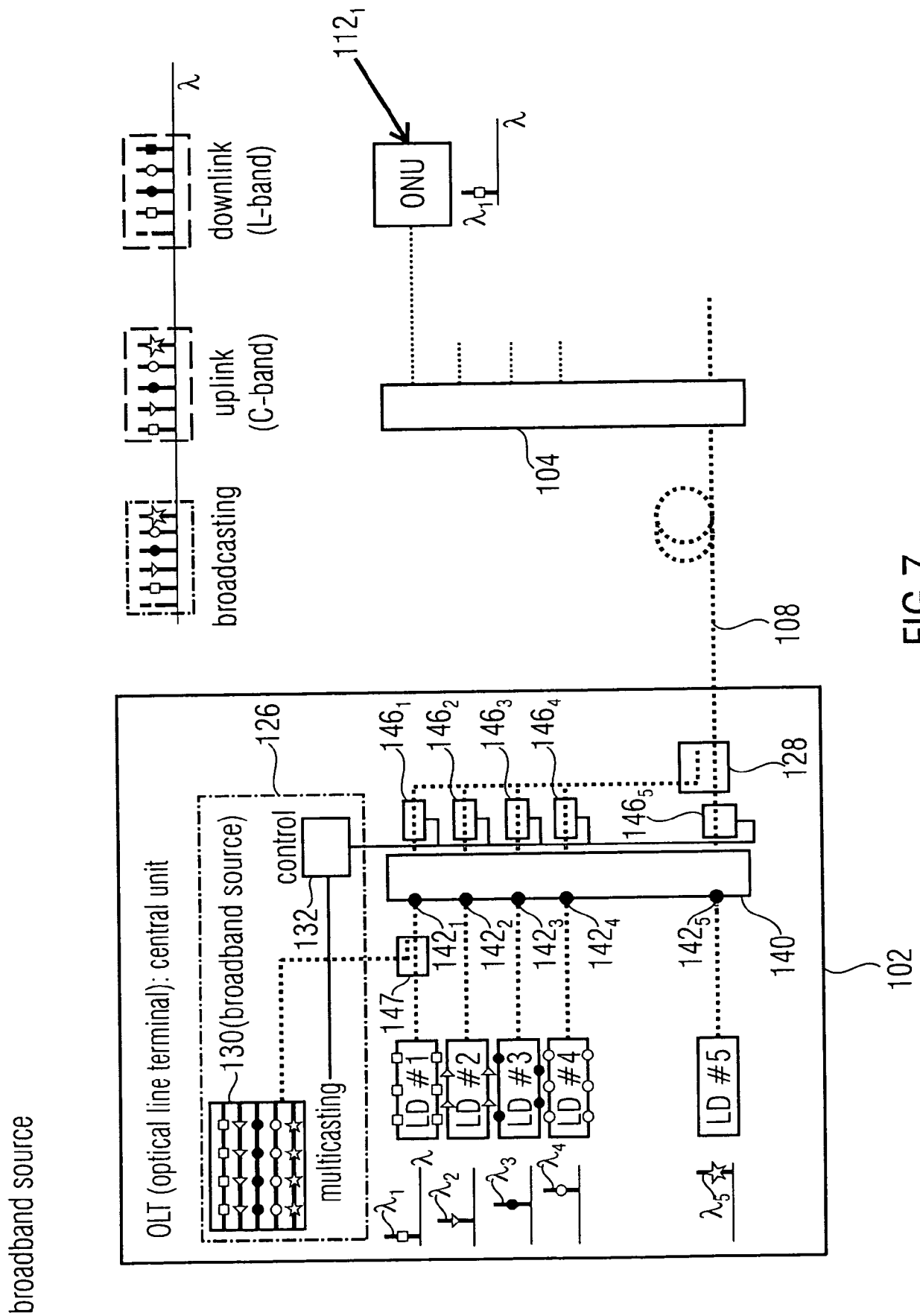


FIG 7

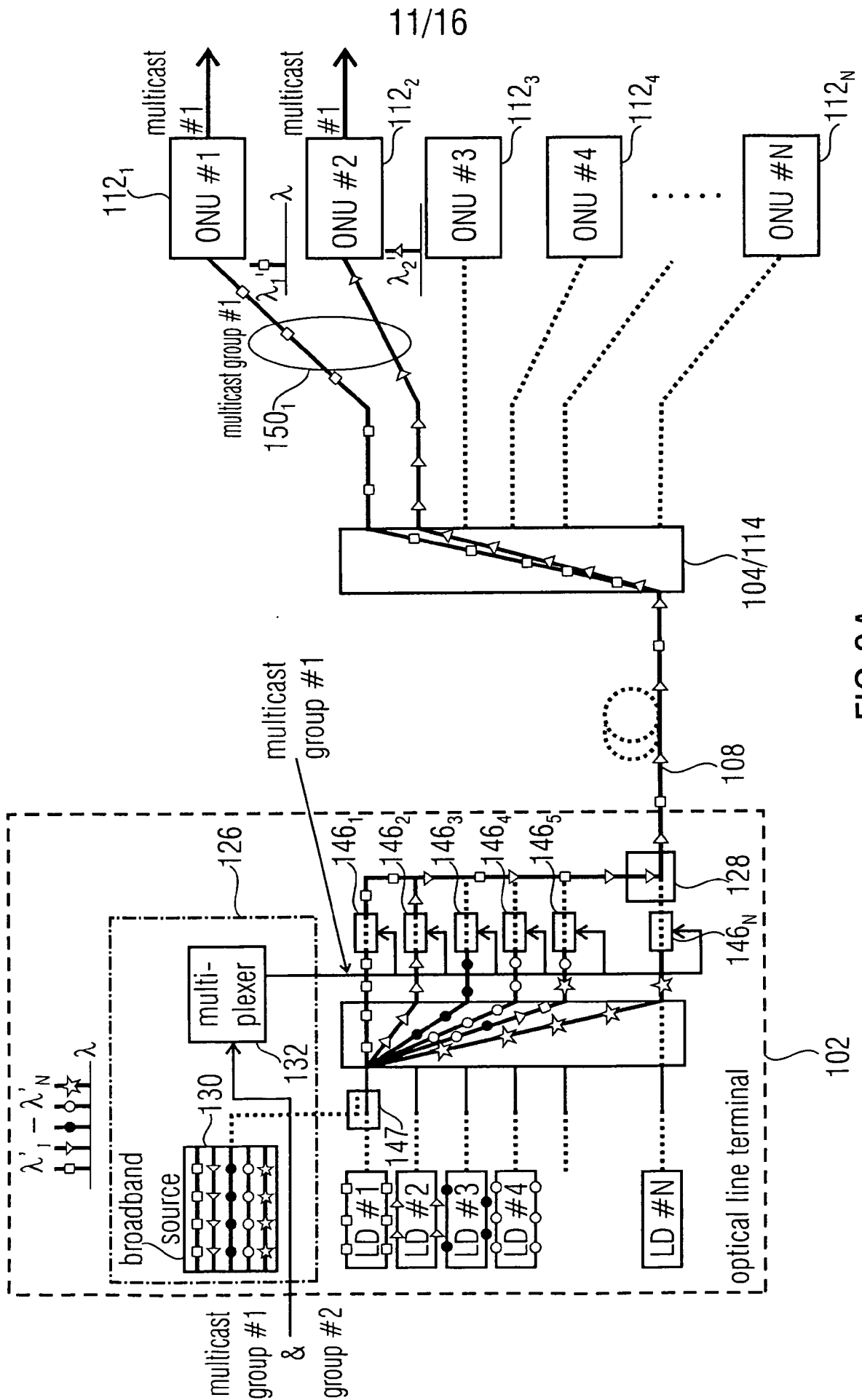


FIG 8A

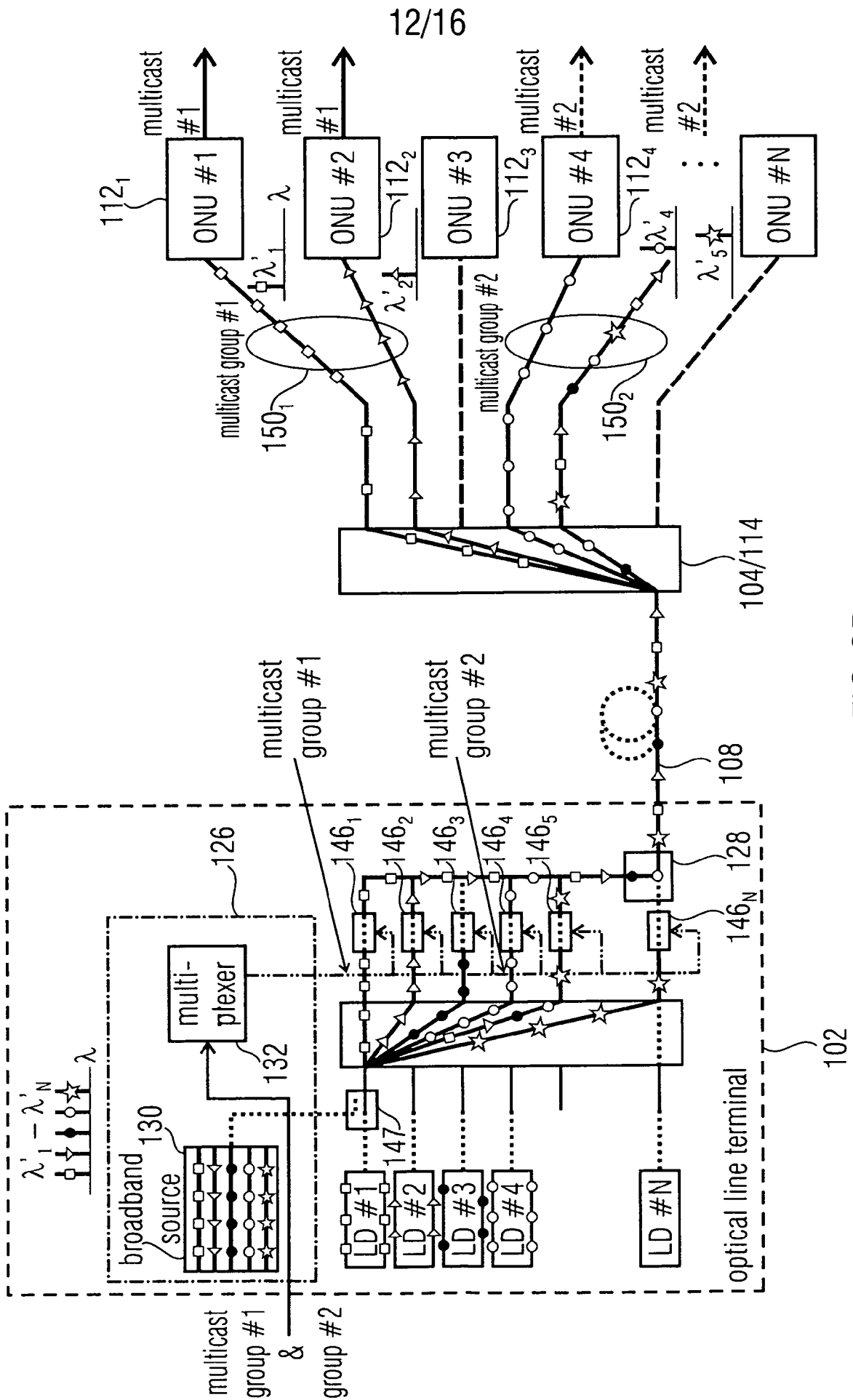


FIG 8B

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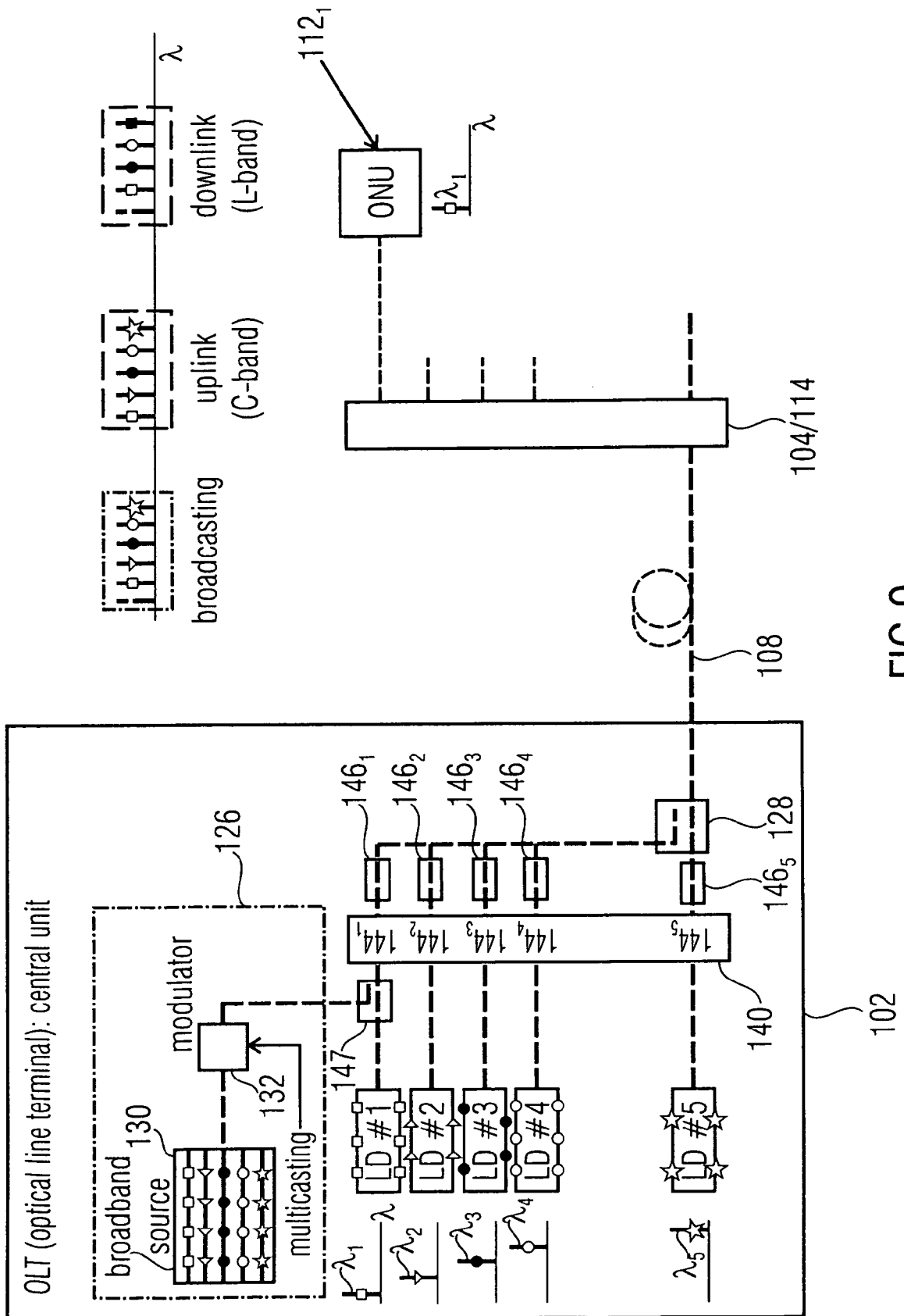


FIG 9

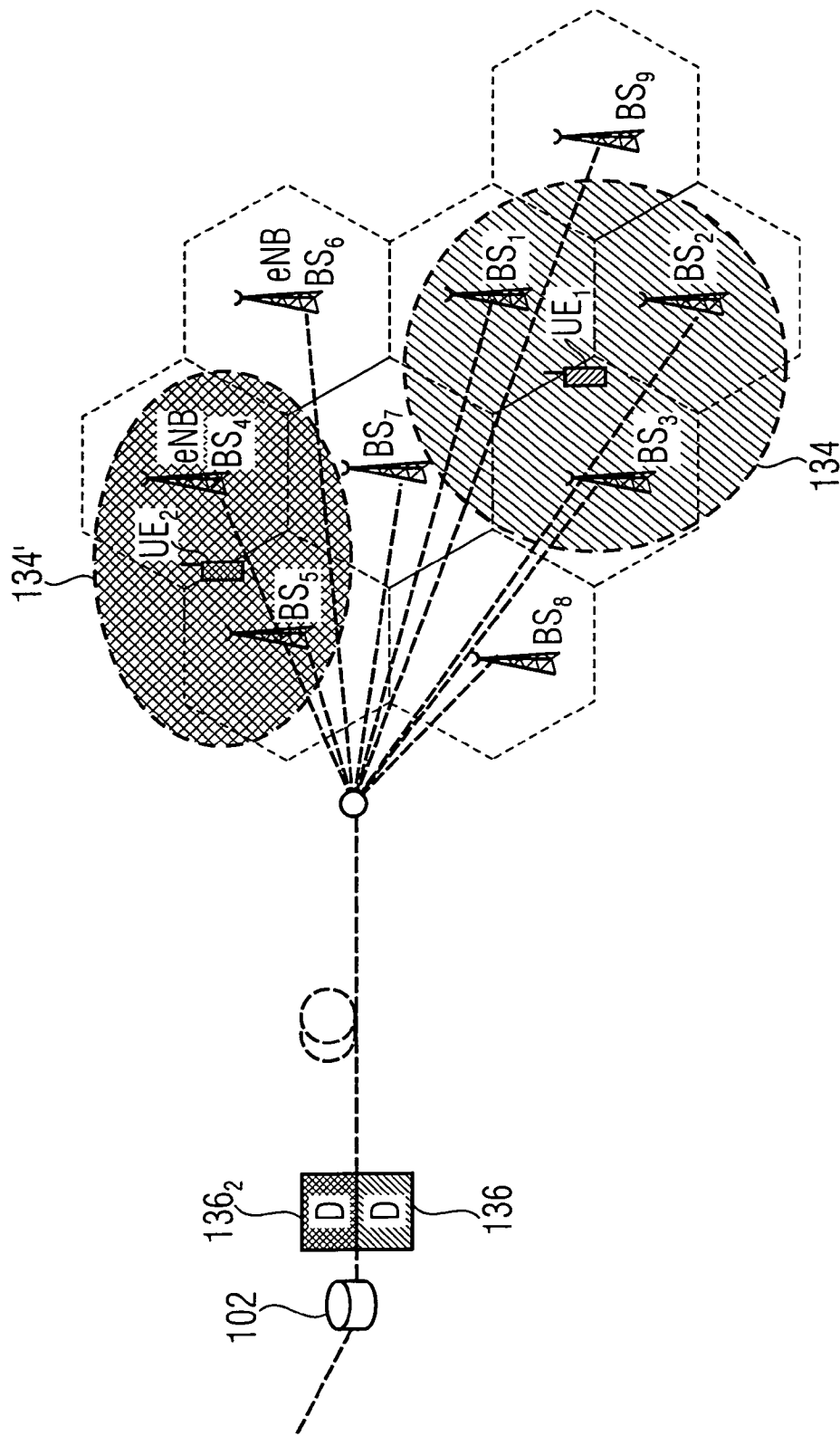


FIG 10A

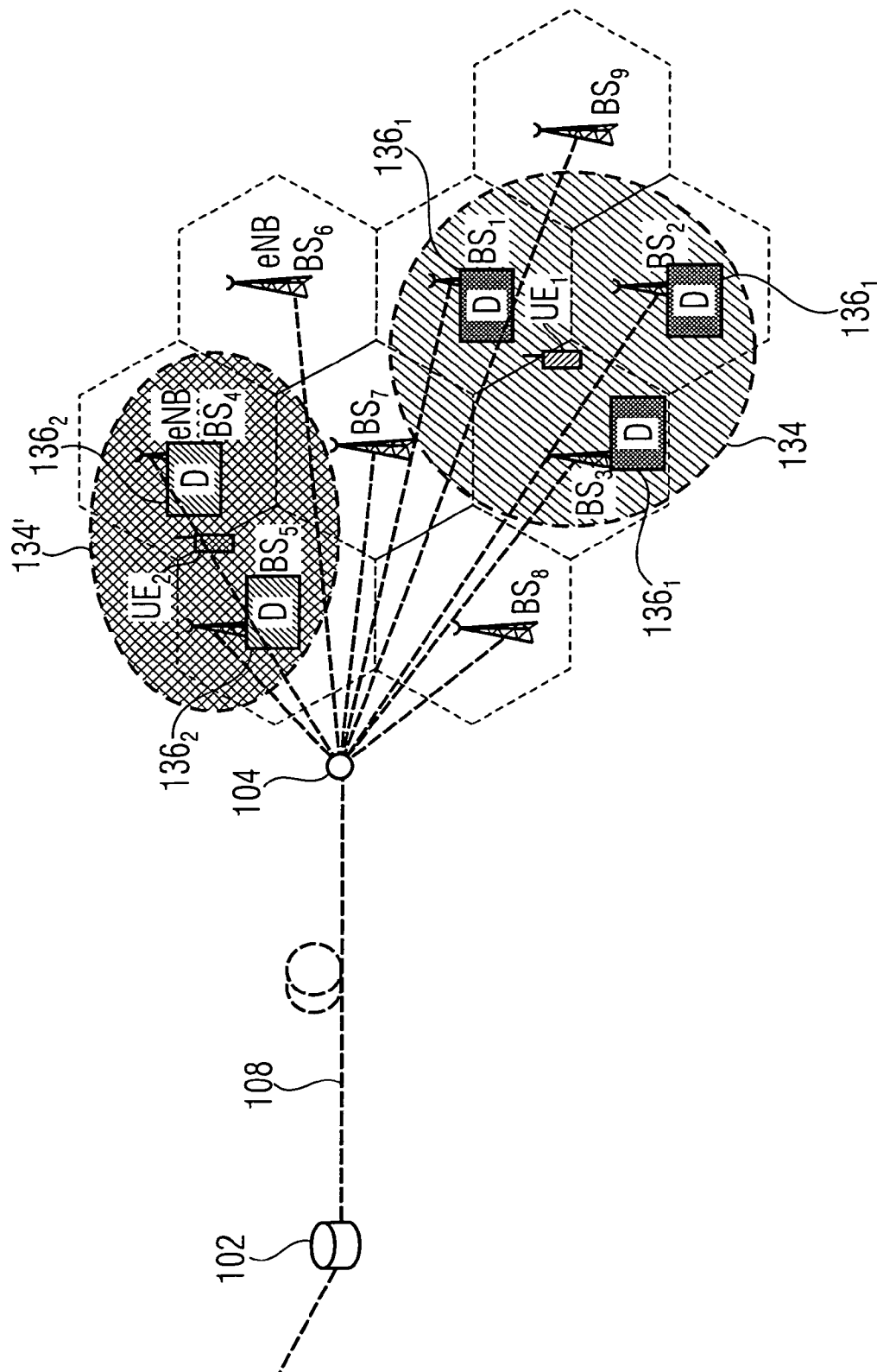


FIG 10B

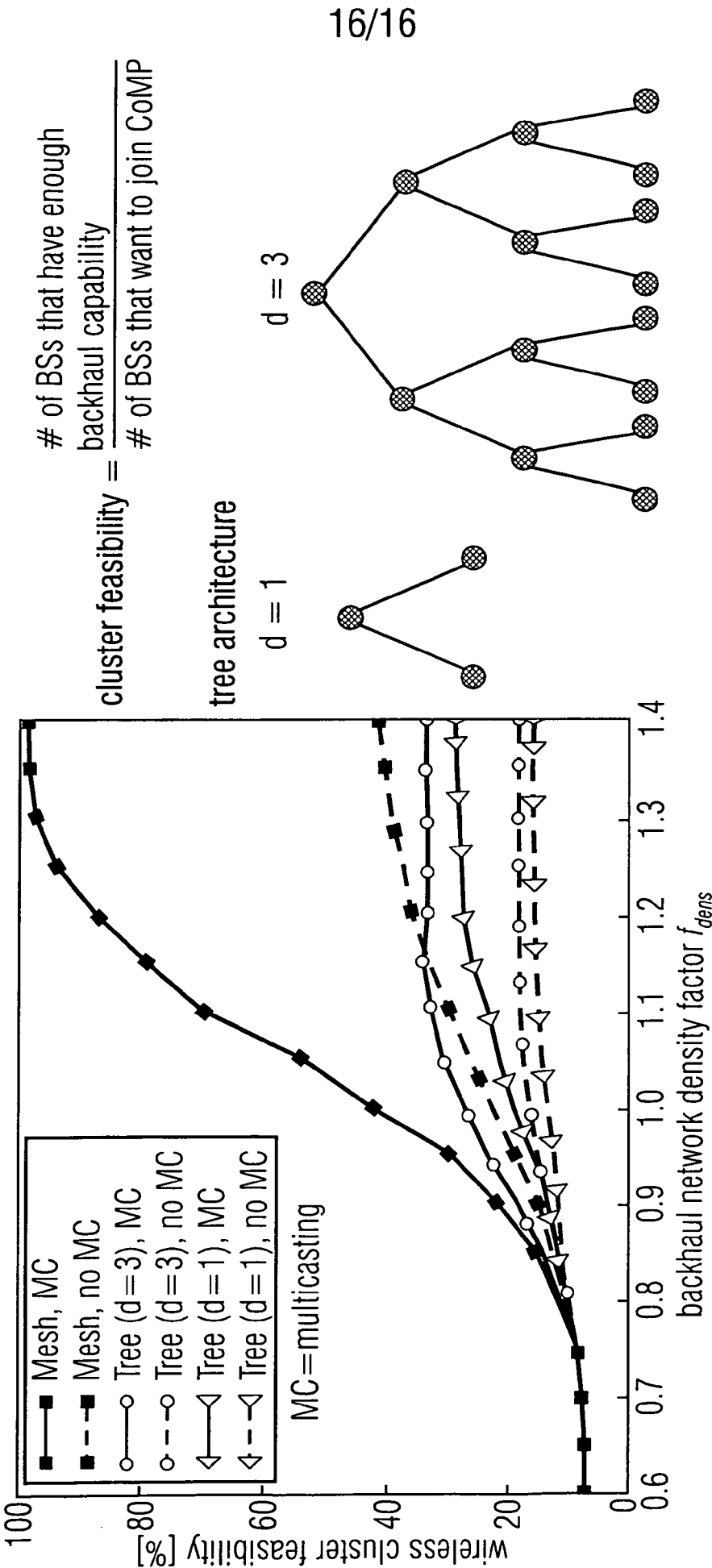


FIG 11

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/060893

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04J14/02
ADD.

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

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

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

EPO-Internal, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JUNG-HYUNG MOON ET AL: "Overlay of broadcasting signal in a WDM-PON", OFCNFOEC. OPTICAL FIBER COMMUNICATION CONFERENCE AND NATIONAL FIBER OPTIC ENGINEERS CONFERENCE,, 1 January 2006 (2006-01-01), page 3PP, XP009093950, DOI: 10.1109/OFC.2006.215757 cited in the application	13-15
A	the whole document	1-12
A	US 2006/045525 A1 (LEE GYU-WOONG [KR] ET AL) 2 March 2006 (2006-03-02) figure 6	1-15

☐

Further documents are listed in the continuation of Box C.

☒

See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

25 October 2012

Date of mailing of the international search report

02/11/2012

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Authorized officer

Dhondt, Erik

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2012/060893

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2006045525 A1	02-03-2006	JP 2006067603 A	09-03-2006
		US 2006045525 A1	02-03-2006
