WAVELENGTH CONFIGURATION METHOD AND APPARATUS FOR MULTI-WAVELENGTH PASSIVE OPTICAL NETWORK, AND MULTI-WAVELENGTH PASSIVE OPTICAL NETWORK SYSTEM

TECHNICAL FIELD

[0001] The present application mainly relates to optical communications technologies, and in particular, to a wavelength configuration method and apparatus for a multi-wavelength passive optical network (Passive Optical Network, PON), and a multi-wavelength passive optical network system.

BACKGROUND

[0002] A passive optical network (PON) technology is currently a main broadband access technology. A conventional PON system is a point-to-multipoint network system based on a time division multiplexing (~~Time Division Multiplexing,~~ TDM) mechanism. Referring to FIG. 1, the PON system generally includes an optical line terminal (~~Optical Line Terminal,~~ OLT) located on a central office side, multiple optical network units (~~Optical Network Unit,~~ ONU) located on a user side, and an optical distribution network (~~Optical Distributing Network,~~ ODN) between the OLT and the ONUs. The ODN is used to distribute or multiplex data signals between the OLT and the ONUs so that the multiple ONUs can share an optical transmission path. In the PON system based on the TDM mechanism, a direction from the OLT to the ONUs is called downstream, the OLT broadcasts a downstream data stream to all the ONUs in a TDM manner, and each ONU receives only data that carries an identifier of the ONU; a direction from the ONUs to the OLT is called upstream. Because all the ONUs share the optical transmission path, in order to prevent a conflict of upstream data between the ONUs, the PON system uses a Time Division Multiple Access (~~Time Division Multiple~~

~~Access,~~ TDMA) manner in the upstream direction. That is, the OLT allocates a timeslot to each ONU, and each ONU sends upstream data in strict accordance with the timeslot allocated by the OLT.

[0003] However, the PON system is affected by a time division characteristic of the TDM mechanism, and available bandwidth of a user is generally restricted. In addition, available bandwidth of a fiber itself cannot be effectively used. Therefore, emerging broadband network application service requirements cannot be satisfied. To solve such a problem and in view of compatibility with an existing PON system, a hybrid PON system that integrates a wavelength division multiplexing (~~Wavelength Division Multiplexing,~~ WDM) technology and the TDM technology is put forward in the industry. In the hybrid PON, multiple wavelength channels are used between an OLT on a central office side and ONUs on a user side to receive and send data. That is, the hybrid PON system is a multi-wavelength PON system.

[0004] In the multi-wavelength PON system, the OLT supports data sending and receiving performed simultaneously by using multiple wavelength channels. Each ONU works on one of the wavelength channels separately. In the downstream direction, the OLT uses a downstream wavelength corresponding to each wavelength channel to broadcast downstream data to multiple ONUs that work on the wavelength channel; in the upstream direction, an ONU on each wavelength channel may send, in a timeslot allocated by the OLT, upstream data to the OLT through an upstream wavelength of the wavelength channel. In order to reduce warehousing costs, the ONU generally uses a wavelength-tunable optical transceiver component. Therefore, an operating wavelength needs to be configured for the ONU during initialization. However, if a downstream receiving wavelength or an upstream ~~transmitting~~ sending wavelength configured by the ONU is not supported by the OLT, the ONU cannot register successfully.

SUMMARY

[0005] The present application provides a wavelength configuration method for a multi-wavelength passive optical network, where the method can effectively ensure normal ONU registration. In addition, based on the wavelength ~~switching~~ configuration method, the present

wavelength of the downstream optical receiver to the selected downstream wavelength.

[0008] A multi-wavelength passive optical network system includes: at least one OLT and multiple ONUs. The at least one OLT is connected to the multiple ONUs in a point-to-multipoint manner through an optical distribution network. The ONU includes the foregoing wavelength configuration apparatus for a multi-wavelength passive optical network.

[0009] In the wavelength ~~switching~~ configuration method and apparatus for a multi-wavelength PON and the multi-wavelength PON system provided in the present application, an ONU scans a wavelength and interacts with an OLT during an initialization process, establishes a corresponding wavelength mapping table, so as to ensure that a transceiver wavelength configured by the ONU is within a wavelength range supported by the OLT, thereby implementing normal initialization of the ONU transceiver wavelength.

BRIEF DESCRIPTION OF DRAWINGS

[0010] To describe the technical solutions in the embodiments of the present invention or in the prior art more clearly, the following briefly introduces the accompanying drawings required for describing the embodiments. Apparently, the accompanying drawings in the following description show merely some embodiments of the present invention, and a person of ordinary skill in the art may still derive other drawings from these accompanying drawings without creative efforts.

[0011] FIG. 1 is a schematic diagram of a network architecture of a passive optical network system based on a time division multiplexing mechanism;

[0012] FIG. 2 is a schematic diagram of a network architecture of a multi-wavelength passive optical network system according to an embodiment of the present application;

[0013] FIG. 3 is a flowchart of a wavelength switching method for a multi-wavelength passive optical network according to a first embodiment of the present application;

[0014] FIG. 4 is a schematic diagram in which an XGTC frame is used to carry wavelength information in the wavelength switching method for a multi-wavelength passive optical network shown in FIG. 3;

[0015] FIG. 5 is a schematic diagram in which a PLOAM message is used to carry wavelength information in the wavelength switching method for a multi-wavelength passive optical network shown in FIG. 3; and

[0016] FIG. 6 is a schematic structural diagram of a wavelength switching apparatus for a multi-wavelength passive optical network according to an embodiment of the present application.

DESCRIPTION OF EMBODIMENTS

[0017] The following clearly and completely describes the technical solutions in the embodiments of the present invention with reference to the accompanying drawings in the embodiments of the present invention. Apparently, the described embodiments are merely a part rather than all of the embodiments of the present invention. All other embodiments obtained by a person of ordinary skill in the art based on the embodiments of the present invention without creative efforts shall fall within the protection scope of the present invention.

[0018] Refer to FIG. 2, which is a schematic diagram of a network architecture of a multi-wavelength passive optical network system 100 according to an embodiment of the present application. The multi-wavelength PON system 100 includes at least one optical line terminal (OLT) 110, multiple optical network units (ONU) 120, and one optical distribution network (ODN) 130, where the OLT 110 is connected to the multiple ONUs 120 in a point-to-multipoint manner by using the ODN 130, and the multiple ONUs 120 share an optical transmission medium of the ODN 130. The ODN 130 may include a feeder fiber 131, an optical splitter module 132, and multiple drop fibers 133, where the optical splitter module 132 may be disposed at a remote node (~~Remote Node,~~ RN). The optical splitter module is connected to the OLT 110 by using the feeder fiber 131 on the one hand and connected to the multiple ONUs 120 separately by using the multiple drop fibers 133 on the other hand.

[0019] In the multi-wavelength PON system 100, a communication link between the OLT 110 and the multiple ONUs 120 may include multiple upstream wavelength channels and multiple downstream wavelength channels. In a downstream direction, the multiple

there is a matching relationship between the upstream wavelength channel identifier and an upstream wavelength of an upstream wavelength channel identified by the upstream wavelength channel identifier, and the OLT 110 and the ONUs 120 may learn the upstream wavelength of the upstream wavelength channel according to the upstream wavelength channel identifier. Similarly, there is also a relationship between the downstream wavelength channel identifier and a downstream wavelength of a downstream wavelength channel identified by the downstream wavelength channel identifier, and the OLT 110 and the ONUs 120 may learn the downstream wavelength of the downstream wavelength channel according to the downstream wavelength channel identifier.

[0022] In an embodiment, referring to FIG. 2, the OLT 110 may include an optical coupler 111, a first wavelength division multiplexer 112, a second wavelength division multiplexer 113, multiple downstream optical transmitters Tx1–Tx4, multiple upstream optical receivers Rx1–Rx4, and a processing module 114. The multiple downstream optical transmitters Tx1–Tx4 are connected to the optical coupler 111 by using the first wavelength division multiplexer 112, the multiple upstream optical receivers Rx1–Rx4 are connected to the optical coupler 111 by using the second wavelength division multiplexer 113, and the coupler 111 is further connected to the feeder fiber 131 of the ODN 130.

[0023] Transmit wavelengths vary between the multiple downstream optical transmitters Tx1–Tx4. Each of the downstream optical transmitters Tx1–Tx4 may correspond to one of the downstream wavelength channels of the multi-wavelength PON system 100. For example, the transmit wavelengths of the multiple downstream optical transmitters Tx1–Tx4 may be λd1–λd4 respectively. The downstream optical transmitters Tx1–Tx4 may use their respective transmit wavelengths λd1–λd4 to transmit downstream data to corresponding downstream wavelength channels separately, so that the downstream data is received by the ONUs 120 that work on the downstream wavelength channels. Correspondingly, receiving wavelengths may vary between the multiple upstream optical receivers Rx1–Rx4. Each of the upstream optical receivers Rx1–Rx4 also corresponds to one of the upstream wavelength channels of the multi-wavelength passive optical network system 100. For example, the ~~transmitting~~ receiving wavelengths of the multiple upstream optical receivers Rx1–Rx4 may be λu1–λu4 respectively. The upstream optical receivers Rx1–Rx4 may use their respective receiving

wavelengths λu1–λu4 to receive upstream data sent by the ONUs 120 that work on the corresponding upstream wavelength channels.

[0024] The first wavelength division multiplexer 112 is configured to: perform wavelength division multiplexing processing on the downstream data that is transmitted by the multiple downstream optical transmitters Tx1–Tx4 and whose wavelengths are λd1–λd4; and send the downstream data to the feeder fiber 131 of the ODN 130 through the optical coupler 111, so as to provide the downstream data for the ONUs 120 by using the ODN 130. In addition, the optical coupler 111 may further be configured to provide the second wavelength division multiplexer 113 with the upstream data that come from the multiple ONUs 120 and whose wavelengths are λu1–λu4, and the second wavelength division multiplexer 113 may demultiplex the upstream data whose wavelengths are λu1–λu4 to the upstream optical receivers Rx1–Rx4 to perform data receiving.

[0025] The processing module 114 may be a Media Access Control (Media Access Control, MAC) module. On the one hand, according to a downstream wavelength channel on which an ONU 120 works, the processing module 114 may provide downstream data that is to be sent to the ONU 120 for a downstream optical transmitter corresponding to the downstream wavelength channel, so that the downstream optical transmitter transmits the downstream data to the wavelength channel; on the other hand, the processing module 114 may also process the upstream data received by each of the upstream optical receivers Rx1–Rx4.

[0026] Operating wavelengths (including an upstream ~~transmitting~~ sending wavelength and a downstream receiving wavelength) of the ONU 120 are tunable. In a specific embodiment, the ONU 120 may include an optical coupler 121, a downstream optical receiver 122, an upstream optical transmitter 123, and a processing module 124. Both the downstream optical receiver 122 and the upstream optical transmitter 123 are wavelength-tunable components, and they may be connected to a drop fiber corresponding to the ONU 120 by using the optical coupler 121. On the one hand, the optical coupler 121 may provide the drop fiber 133 of the ODN 130 with the upstream data sent by the upstream optical transmitter 123, so as to send the upstream data to the OLT 110 through the ODN 130; on the other hand, the optical coupler 121 may further provide the downstream optical receiver 122 with the downstream data sent

by the OLT 110 through the ODN 130, so as to perform data receiving.

[0027] The processing module 124 may be a MAC module. On the one hand, the processing module 124 may control, according to needs, the downstream optical receiver 122 and the upstream optical transmitter 123 to perform wavelength adjustment. On the other hand, the processing module 124 may provide, in a specified timeslot, the upstream optical transmitter 123 with the upstream data to be sent to the OLT 110, so that the upstream optical transmitter 123 sends the upstream data to the OLT 110 through a corresponding upstream wavelength channel, and the processing module 124 processes the downstream data received by the downstream optical receiver 122.

[0028] In the multi-wavelength PON system, because the OLT 110 supports multiple upstream and downstream wavelength channels and the operating wavelengths of the ONU 120 are tunable, in order to implement normal registration, a downstream receiving wavelength and an upstream ~~transmit~~ sending wavelength need to be first configured for the ONU 120 according to a wavelength capability supported by the OLT 110 during initialization. A wavelength configuration method for a multi-wavelength PON system according to an embodiment of the present invention can ensure correct initialization of an operating wavelength of an ONU.

[0029] FIG. 3 is a flowchart of a wavelength configuration method for a multi-wavelength passive optical network according to an embodiment of the present application. The wavelength configuration method may include:

[0030] Step S10: An OLT periodically broadcasts, on each downstream wavelength channel of a multi-wavelength PON system, downstream wavelength information of each downstream wavelength channel and information of an upstream wavelength that is available for ONU registration.

[0031] In one aspect, a MAC module of the OLT on a central office side may provide the downstream wavelength information of each downstream wavelength channel for corresponding downstream optical transmitters Tx1–Tx4 separately, and control the downstream optical transmitters Tx1–Tx4 to periodically broadcast the downstream wavelength information to ONUs on a user side through each downstream wavelength channel. Because each downstream wavelength channel corresponds to a specific downstream

wavelength, in an embodiment, the downstream wavelength information broadcast by the OLT on each wavelength channel may be channel identifier information of the downstream wavelength channel, such as a downstream wavelength channel number.

[0032] In another aspect, the MAC module of the OLT may further obtain, with reference to the number of ONUs that are actually online on each upstream wavelength channel and according to an algorithm for balancing the numbers of ONUs on wavelength channels, the upstream wavelength information that is available for ONU registration, that is, available-upstream-wavelength information. In addition, the MAC module may provide the upstream wavelength information for the downstream optical transmitters Tx1–Tx4, so that the downstream optical transmitters Tx1–Tx4 implement broadcasting of the available-upstream-wavelength information simultaneously when broadcasting the downstream wavelength through each downstream wavelength channel.

[0033] In an embodiment, the downstream wavelength information and the upstream wavelength information may be carried by an XGPON transmission convergence (~~XGPON Transmission Conversion,~~ XGTC) frame, a GPON transmission convergence (~~GPON Transmission Conversion,~~ GTC) frame or an Ethernet frame (that is, EPON frame) having a logic link identifier (~~Logic Link Identifier,~~ LLID).

[0034] An example is used, in which an XGTC frame is used to carry the downstream wavelength information and the upstream wavelength information. Referring to FIG. 4, the XGTC frame includes an XGTC frame header and an XGTC payload, where the XGTC frame header includes an optical network unit identifier (ONU-ID) field, an indication (Ind) field, a hybrid error correction (~~Hybrid Error Correction,~~ HEC) field and a physical layer operations, administration and maintenance upstream (~~Physical Layer Operations, Administration and Maintenance upstream,~~ PLOAMu) field, where the downstream wavelength information and the upstream wavelength information may be carried by the Ind field. For example, a reserved (Reserve) field of 9 bits is reserved in the Ind field of the XGTC frame header defined in an existing XGPON standard. In this embodiment, the downstream wavelength information and the upstream wavelength information may be carried by the reserved field in the Ind field of the XGTC frame header.

[0035] In another embodiment, the downstream wavelength information and the upstream

wavelength information may be carried by a physical layer operations, administration and maintenance (~~Physical Layer Operations, Administration and Maintenance,~~ PLOAM) message, an ONT management and control interface (~~ONT Management and Control Interface,~~ OMCI) message, a Multi-Point Control Protocol (~~Multi-Point Control Protocol,~~ MPCP) message or an operation, administration and maintenance (~~Operation Administration and Maintenance,~~ OAM) message. A specific message format, such as a field value and a field length, may be determined according to actual needs. Certainly, in another alternative embodiment, the OLT 110 may also carry a downstream wavelength switching command by a newly defined message.

[0036] An example is used, in which a PLOAM message is used to carry the downstream wavelength information and the upstream wavelength information. Referring to FIG. 5, FIG. 5 is a schematic diagram of a message format of the PLOAM message. The PLOAM message usually includes an optical network unit identifier (ONU ID) field, a message identifier (Message ID) field, a sequence number (Sequence No) field, a data (Data) field, and an integrity check (Integrity Check) field. In this embodiment, the downstream wavelength information and the upstream wavelength information may be carried in the data field of the PLOAM message. For example, the PLOAM message may use the format shown in the table below:

Byte (Octet)	Content (Content)
1–2	ONU identifier (ONU ID)
3	Message identifier (Message ID)
4	Sequence number (Sequence No)
5–a	Downstream wavelength information (OLT Tx Wavelength)
(a+1)–b	Upstream wavelength information (ONU registration Wavelength)
(b+1)–40	Reserved (Reserved)
41–48	Message integrity check (MIC)

[0037] Step S20: An ONU scans a downstream receiving wavelength, receives a downstream receiving optical physical parameter, and establishes a downstream receiving

ONU, and the information about the peak value of the receiving optical current of the OLT in an upstream receiving wavelength mapping entry correspondingly established by the OLT is replaced by the peak value of the receiving optical power of the OLT or the RSSI peak value or the another physical parameter.

[0053] By repeating the foregoing process, the upstream sending wavelength scanning of the ONU may traverse all upstream ~~transmitting~~ sending wavelengths supported by the upstream optical transmitter or a whole upstream ~~transmitting~~ sending wavelength range of the upstream optical transmitter. Therefore, the OLT may establish one or more upstream receiving wavelength mapping entries. After the foregoing upstream sending wavelength scanning is completed, the OLT may establish the upstream receiving wavelength mapping table including one or more entries, and each entry therein corresponds to different upstream receiving wavelengths.

[0054] Step S60: The OLT sends the upstream receiving wavelength information to the ONU, and the ONU establishes an upstream sending wavelength mapping table according to the upstream receiving wavelength information, where an entry of the upstream sending wavelength mapping table includes upstream sending wavelength information and drive current information of an upstream optical transmitter.

[0055] For example, when the OLT finds that the ONU performs registration on one same upstream wavelength channel for the second time, the MAC module of the OLT may compare a currently detected value of the receive optical current of the OLT with the recorded peak value of the receive optical current of the OLT, so as to determine whether a deviation between them is less than a preset threshold. If the deviation is less than the threshold, it may be considered that the current upstream sending wavelength of the ONU is aligned with the current upstream receiving wavelength of the OLT, and the OLT may send the upstream wavelength information that is of the upstream wavelength channel and corresponds to the peak value of the receiving optical current of the OLT to the ONU. After the ONU receives the upstream wavelength information, the ONU may establish a corresponding upstream sending wavelength mapping table, where an entry of the upstream sending wavelength mapping table may include the upstream sending wavelength information (that is, the upstream wavelength information provided by the OLT) and the drive current information of the upstream optical transmitter of the ONU.

receiving optical power of the ONU or an RSSI value) with the peak value of the receiving optical current of the ONU (or the peak value of the receiving optical power of the ONU or the RSSI peak value) recorded in the related entry of the downstream receiving wavelength mapping table. If a deviation between them is greater than a preset threshold, it is considered that a drift occurs on the downstream receiving wavelength of the downstream optical receiver of the ONU. In this case, the ONU may randomly select one direction to adjust the downstream receiving wavelength of the downstream optical receiver, and continue to measure the receiving optical current of the ONU (or the value of the receiving optical power of the ONU or the RSSI value) during the adjustment process. If the value of the measured receiving optical current of the ONU (or the value of the receiving optical power of the ONU or the RSSI value) is decreased, the downstream receiving wavelength is adjusted in an opposite direction until a deviation between the value of the measured receiving optical current of the ONU (or the value of the receiving optical power of the ONU or the RSSI value) and the peak value of the receiving optical current of the ONU (or the peak value of the receiving optical power of the ONU or the RSSI peak value) is less than the preset threshold.

[0062] Step S90: The OLT monitors, according to the upstream receiving wavelength mapping table, whether a drift occurs on an upstream ~~transmitting~~ sending wavelength of the ONU, and instructs the ONU to calibrate the upstream ~~transmit~~ sending wavelength when the drift occurs.

[0063] Specifically, during a normal communication process, the OLT may monitor the receiving optical current of the OLT (or the receiving optical power of OLT or the RSSI), and compare a value of the monitored receiving optical current of the OLT (or a value of the receiving optical power of the OLT or an RSSI value) with the peak value of the receiving optical current of the OLT (or the peak value of the receiving optical power of the OLT or the RSSI peak value) recorded in the related entry of the upstream receiving wavelength mapping table. If a deviation between them is greater than a preset threshold, it is considered that a drift occurs on the upstream ~~transmitting~~ sending wavelength of the upstream optical transmitter of the ONU. In this case, the OLT may deliver a wavelength adjustment instruction to the ONU, so as to instruct the ONU to randomly select one direction to adjust the upstream sending wavelength of the upstream optical transmitter. The OLT continues to measure the receiving optical current of OLT (or the value of the receiving optical power of the OLT or the RSSI

value) during the process of adjusting the upstream sending wavelength the ONU. If it is measured that the value of the receiving optical current of the OLT (or the value of the receiving optical power of the OLT or the RSSI value) is decreased, the OLT delivers the wavelength adjustment instruction to the ONU again, so as to instruct the ONU to adjust the upstream sending wavelength in an opposite direction, until a deviation between the value of the measured receiving optical current of the OLT (or the value of the receiving optical power of the OLT or the RSSI value) and the peak value of the receiving optical current of the OLT (or the peak value of the receiving optical power of the OLT or the RSSI peak value) is less than the preset threshold.

[0064] In the wavelength configuration method for a multi-wavelength passive optical network according to the embodiment of the present application, an ONU scans a wavelength and interacts with an OLT during an initialization process, and establishes a corresponding wavelength mapping table, so as to ensure that a transmitting wavelength and a receiving wavelength configured by the ONU are within a wavelength range supported by the OLT, thereby implementing normal initialization of the transmitting wavelength and the receiving wavelength of the ONU. In another aspect, whether a drift occurs on the transmitting wavelength and the receiving wavelength of the ONU can be monitored in real time based on the wavelength mapping table during a normal communication process, and auto-adjustment is performed when the drift occurs, thereby ensuring signal receiving quality and reducing a bit error rate.

[0065] Based on the wavelength ~~switching~~ configuration method for a multi-wavelength passive optical network system according to the foregoing embodiment, the present application further provides a wavelength ~~switching~~ configuration apparatus. The wavelength switching apparatus may be applied to the ONUs 120 in the multi-wavelength passive optical network system 100 shown in FIG. 2. Referring to FIG. 6, FIG. 6 is a schematic structural diagram of a wavelength configuration apparatus 600 for a multi-wavelength passive optical network system according to an embodiment of the present application. The wavelength configuration apparatus 600 may include:

a receiving module 610, configured to scan a downstream receiving wavelength, and receive, during the process of scanning the downstream receiving wavelength,